



**THE NUTRITIONAL COMPOSITION AND ACCEPTABILITY OF *MORINGA OLEIFERA*
LEAF POWDER (MOLP)-SUPPLEMENTED *MAHEWU*: A MAIZE MEAL-BASED
BEVERAGE FOR IMPROVED FOOD AND NUTRITION SECURITY**

BY

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ABSTRACT

Adequate nutrition is widely recognized as an essential element for a healthy and productive lifestyle. However, poor nutrition, which leads to preventable health challenges, remains a critical global challenge. Over two billion persons worldwide suffer from micronutrient deficiencies, with many at risk of problems resulting from deficiencies in vitamins A and B, iodine, zinc, and iron. Despite the recent rigorous food and nutrition intervention programs to tackle protein and energy malnutrition (PEM) as well as micronutrient deficiency, the challenges continue to rise. Compromised diets that mainly rely on starchy foods such as maize without other rich sources of essential protein, vitamins and minerals are among the leading factors contributing to the burden of morbidity and mortality associated with malnutrition among the rural population sub-Saharan Africa South Africa inclusive. Malnutrition especially micronutrient deficiencies mostly affects young children and women of childbearing age. *Moringa Oleifera* (M.O) commonly known as *Moringa* is reported to offer highly nutritious food components. The plant originates from India and is generally used more as a medicinal plant than as food. *Moringa* can be found in many parts of the world, including southern Africa. Its leaves can be processed into powder, enabling its use as a nutrient supplement in foods. Although the *Moringa oleifera* plant is well known as an excellent nutrient source, its acceptability for use in *Mahewu* (a South African non-alcoholic beverage) has not been tested. All age groups popularly consume *Mahewu* as a refreshing and filling drink. It is prepared in most rural households, especially during summer seasons, by fermenting cooked maize meal (porridge) to produce a desired sensory attribute (sour taste). This study investigated the effects of incorporating *Moringa oleifera* leaf powder (MOLP) as a nutritional supplement in *Mahewu*, with a focus on the nutritional composition and consumer acceptability of the resulting supplemented beverage. The study was conducted at Ntambanana, KwaZulu-Natal, a rural area in South Africa where *Moringa* is grown. A survey of 46 randomly selected households was undertaken to investigate the utilization and perceptions of *Moringa oleifera*. The survey was complemented by focus group discussions of 1-12 individuals from randomly selected households. Moreover, key informant interviews were used to further verify the utilization of *Mahewu* and perception of *Moringa oleifera*. A standard recipe for preparing one litre of *Mahewu* was developed based on the recipe used by indigenous people. This was used to prepare reference samples for all the experiments. Beside the control sample, three prototypes of MOLP-supplemented *Mahewu* at 2%, 4%, and 6% ratios respectively were prepared for nutritional analysis. The nutritional composition of the control and MOLP supplemented samples (0%, 2%, 4%, and 6 %) were determined by the standard methods of the Association of Official Analytical Chemists (AOAC). The proximate and the selected mineral content were determined. A sensory evaluation was conducted using 52

untrained panellists who were *Mahewu* consumers. The consumption of *Mahewu* was reported to be at its highest peak in summer (43.5%), and lowest in autumn (2.2%). Chi-square test analysis revealed a significant difference ($p < 0.05$) between the frequency in consumption and the reason for its consumption. There was a low addition of nutritive food items or fortification of the drink (*Mahewu*), as 84% of the respondent's only added sugar when preparing the beverage as a fermentation enhancer and for taste, only 2.2% added fruits, while 13.3% add nothing to their *Mahewu* drink. Fortification of the beverage is important because the community mostly relied on locally produced (conventional) maize which was processed into maize meal for use in preparing *Mahewu*, and only bought fortified maize after their harvesting period was over. Conventional maize tends to be inadequate in nutritional value and could hence increase the risks of hidden hunger if consumed without any supplementation or fortification. It was surprising that although *Moringa* was planted in the community, 78.3% of the locals did not know much about its properties as a highly nutritious plant. Findings of nutritional analysis reveals that *proximate* and selected minerals contents of raw materials were high in MOLP; $p < 0.05$ compared to maize meal. Consequently increased concentration of MOLP in *mahewu*, macronutrient and selected mineral content of supplemented samples were enhanced significantly $p < 0.05$. The percentage increase of selected minerals include: Calcium 350 in 2% sample, 700 in 4% sample and 950 in 6% sample, respectively. Iron 105.76 in 2% sample, 213.46 in 4% sample and 286.54 in 6% sample, respectively. Manganese: 2% sample 28.57, 4% sample 35.71 and 6% sample 50, respectively.

Sensory evaluation revealed that the, MOLP-supplemented *Mahewu* at 2% and 4% MOLP concentration were found to be as acceptable similar to the conventionally prepared *Mahewu*. The investigation therefore conclude that incorporation of MOLP in *Mahewu* substantially enhances *mahewu* nutritional value without compromising its acceptability. However in future study, 6% MOLP sample might need to be masked for better acceptability with respect to the aroma, taste and color.

PREFACE

The work described in this dissertation was carried out in the discipline of Food Security, School of Agricultural, Earth and Environmental Sciences, at the University of KwaZulu-Natal, South Africa. This was undertaken within the 2016 and 2017 academic sessions, under the supervision of Prof. Unathi Kolanisi and Dr. Annette Van Onselen.

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Date: 27 June 2018

Dr. Annette Van Onselen (Co-Supervisor)

DECLARATION

I, Ruth Nachamada Olusanya (215081315), declare that:

1. The research reported in this dissertation, except where otherwise indicated is my original work.
2. This dissertation, or any part of it, has not been submitted for any degree or examination at any other university
3. Where other sources have been used, they have not been copied and have been acknowledged properly.
4. This dissertation does not contain text, graphics or tables copied and pasted from the internet, unless specifically acknowledged and the source being detailed in the dissertation and in the relevant reference section.

Signed:



Date: 26 June, 2018

Ruth Nachamada Olusanya (Candidate)

DEDICATION

This dissertation is dedicated to God Almighty “*For in him we live and move and have our being*” (Acts 17:28).

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RESEARCH OUTPUT

1. Poster Presentation at BRICS conference September 2016, Durban, Republic of South Africa

Titled: The African traditional production of Kunu and *Mahewu* fermented cereal beverages for food and nutrition security

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LIST OF ABBREVIATIONS

DALYs	Disability Adjusted Life Years
MND	Micronutrient deficiency
FAO	Food and Agricultural Organization
WHO	World health organization
CVD	Cardiovascular diseases
PEM	Protein and Energy Malnutrition
MDG	Millennium Development Goal
Oxfam	Oxford Committee for Famine Relief
SSA	Sub-Saharan Africa
SA	South Africa
NCDs	Non-communicable diseases
SANHANES	South African National Health and Nutrition Examination Survey
MOLP	<i>Moringa Oleifera</i> leaf powder
MO	<i>Moringa Oleifera</i>
MOLPSFP	<i>Moringa Oleifera</i> leaf powder-supplemented food products
NGP	National Gross Product
ADF	Acid detergent fiber
NDF	Neutral detergent fiber
FGD	Focus group discussion

CHAPTER 1

INTRODUCTION

1.1 Background to the Study

Micronutrient deficiency (MND), a form of malnutrition, persists as a serious global concern and a topic of interest for research (Fayemi *et al.*, 2016). Micronutrient deficiencies result from a lack/insufficient intake of essential vitamins and minerals, which negatively affects immunity, growth, development, and general well-being. Micronutrient deficiency is often associated with clinical symptoms of diseases that can be prevented or alleviated through nutritional therapy. Despite the global agenda and programs established towards combating malnutrition, micronutrient deficiency challenges are still prevalent in countries of Sub-Saharan Africa (SSA). It has been estimated that over two billion people are at risk of MND health challenges (De-Regil *et al.*, 2013). A dietary survey in the United Kingdom (UK) and sub-Saharan African countries confirms that vitamin A, zinc, iron, calcium, vitamin D and iodine deficiencies are among the leading problems worldwide (De-Regil *et al.*, 2013, WHO, 2017a).

The awakening concern for scholars researching on better strategies to combat malnutrition is due to the potential of health risks associated with malnutrition. Malnutrition mostly affects individuals from poorly-resourced households and limits many populations from exploring their potential, resulting in the inability to work, thereby affecting livelihoods. This has serious economic consequences and compromises national development worldwide (WHO, 2017a). According to Fayemi *et al.* (2016), malnutrition (including micronutrient deficiencies) is a determinant of food and nutrition insecurity, which is a forerunner for most non-communicable health challenges (Fayemi *et al.*, 2016). Most health implications of malnutrition are derived from long-term nutrient inadequacies in the foods consumed, resulting in ‘hidden hunger’. Some of the resulting diseases include night blindness, anemia and a host of others. It is identified that micronutrient deficiencies can aggravate other chronic diseases on the human body (Tulchinsky, 2010).

Several studies reveal that micronutrient deficiencies affect young children from infancy and above. Further, study claims the deficiencies affect all genders and also people of different socioeconomic status (Ahmed *et al.*, 2013). Although the most affected are subcategories of a population such as women of child-bearing age and children under five years of age who are mostly from poorly resourced settings (Muthayya *et al.*, 2013a, Miller *et al.*, 2016). The aged,

whose appetite for food is reduced or affected, and people who are suffering from chronic diseases can also be predisposed to MND challenges. Long-term reliance on poor diets and staple foods of cereal and other starch-based food products with additional sources of micronutrient rich foods is known to supply inadequate nutrients. This has long been a challenge obstructing malnutrition mitigation strategies, such as the United Nation (UN) Sustainable Developmental Goals (2030 Plan). Consequently, it makes it difficult to achieve food and nutrition security of individuals, the second (Zero Hunger) and third goals (good health and well-being) of the UN (De-Regil *et al.*, 2013, WHO, 2017a).

Categorically, there are two forms of malnutrition: over-nutrition, which is the excess intake of energy or micronutrients, and the second under-nutrition, an inadequate intake or absorption of essential vitamins and minerals (Gautam, 2014). Besides the leading aforementioned deficiencies (WHO, 2017b), deficiencies of vitamin B12 and other B vitamins are commonly prevalent. There are reports in the literature that more than one micronutrient deficiency exists and of the leading deficiencies including the B Vitamins deficiency are prevalent in many developing countries (Muthayya *et al.*, 2013a). Micronutrient deficiencies are escalating in developing countries, particularly in sub-Saharan Africa, including South Africa. The situation is more common among low-income rural households and within the urban setting, where people have adopted poor dietary lifestyles coupled with reduced body activity. In South Africa (SA), one in every four people suffers from hunger, as approximately over fifteen million people are receiving social grants (Tsegay *et al.*, 2014). According to the Oxford Committee for Famine Relief (OXFAM), 26% of South Africa's population is regularly experiencing hunger and an additional 28% is in jeopardy of hunger (SANHANES, 2013). The largest groups that are experiencing hunger are those that live in urban (32.4%) and rural (37.0%) informal settlements. The same areas account for the largest percentages at risk of hunger: 36.1% in urban informal areas and 32.8% in rural informal areas. Adequate food is noted as being necessary for optimum health. According to (Tsegay *et al.*, 2014), where food insecurity lingers there is a high probability of micronutrient deficiency challenges.

Furthermore, malnutrition status is accompanied by a rise in the prevalence of non-communicable diseases (NCDs) such as cardiovascular disease, cancer, diabetes, chronic lung diseases and obesity (Lee *et al.*, 2012). These diseases are described as the greatest killers and deprivors of livelihoods, limiting lifespan and economic development. According to Popkin *et al.* (2012), hidden hunger and NCDs are consequences that emerged from unhealthy lifestyle

food choices, monotonous diets, and poor diet preferences. An unhealthy diet is one of the four primary risk factors leading to diseases and deaths in the world (Tsegay *et al.*, 2014). Almost three-quarters of all NCD-related deaths, and 82% of the 16 million people who die prematurely or before reaching 70 years of age, are associated with poor diets and mostly occur in low- and middle-income countries (WHO, 2017b). Another leading cause of malnutrition is the limited consumption of fruits and vegetables (Lewu and Mavengahama, 2011). This has been shown in studies that investigate the global mean score of dietary diversity. The utilization of vegetables and other foods that are rich in essential nutrients is very low, especially where restricted access to healthy and nutritious food occurs. Some NCDs occur due to changes in dietary lifestyles, such as inclinations to indigenous produce or poor attitudes to food (Labadarios *et al.*, 2011). Monotonous diets, without vegetables and fruits, are a great contributing factor to most of the micronutrient deficiency challenges.

Interventions such as fortification of commercial foods consumed by a large population and the use of synthetic food supplements have been carried out to address the malnutrition problem. However, it has been reported that fortification is more of a “post-processing” intervention that does not necessarily integrate agricultural practices with nutritional outcomes. It is reported that most of these interventions are affected by socio-economic factors, such as education, women empowerment, cultural beliefs, infant feeding practices, intra-household food distribution and social norms (Burchi *et al.*, 2011). Other nutritional interventions include education and working with women. Women are regarded as agents of change in the nutritional status of communities. Currently, the World Health Organization (WHO) issued a recent call about encouraging diversified diets through the consumption of green leafy vegetables, fruits and legumes (WHO, 2009). However, the emphasis of this call appears more on the utilization of locally available and indigenous fruits and vegetables.

(Kataki, 2002, Burchi *et al.*, 2011). A study argue that most of the food and nutrition intervention strategies fail to achieve their mandatory goals because the interventions often underestimate the existing linkages between health, culture, environment, agriculture, and nutrition, which affect local food systems(Kataki, 2002). All the food-based intervention strategies should be context-based and complemented by education in order to improve the utilization of fortified/supplemented foods for increasing nutrient diversity. This study explores the use of *Moringa Oleifera* (common name ‘*Moringa*’) as a food ingredient to enhance the staple beverage *mahewu*. *Moringa Oleifera* is a nutrient-rich plant that has gained recognition and popularity in sub-Saharan Africa. The plant has been reported to have potential in

maintaining a healthy life if incorporated into the food system (Mahmood *et al.*, 2010). The use of *Moringa* has been documented in more than 80 countries of the world and the plant is known in over 200 local languages, with over 300 references to it in Ayurvedic medicine (an old medical system) (*Moringa* Benefits, 2009), for example. The leaves of *Moringa* are identified by the World Vegetable Center in Taiwan as a notable vegetable with the highest nutritional content among 120 types of food species studied (Kase, 2015). *Moringa* is a multi-purpose plant with virtually every part being useful, notably the roots, leaves, flowers, and seeds (Jideani and Diedericks, 2014). The leaves have high amounts of essential amino acids, minerals and vitamins (especially the B vitamins) (Fuglie and Lowell Fuglie, 2001). Studies on the properties of *Moringa oleifera* indicate that its leaves contain more vitamin A than carrots, more iron than in spinach, more calcium than in milk, more vitamin C than in oranges, and more potassium than in bananas. The value of protein in *Moringa* leaves exceeds that of milk and eggs (Anwar *et al.*, 2007, Jideani and Diedericks, 2014). Furthermore, the leaves, roots, seed, bark, fruit, flowers and immature pods have been used for curative purposes in the indigenous system of medicine, particularly in south Asia. *Moringa* has been reported to have properties that cure and reduce swelling, boosts both the human and animal immune system and stimulate and increase sex drive. It also prevents pregnancy as it increases the flow of breast milk (WebmD, 2005-2016).

Various studies affirm that *Moringa* can be used both as a food and a herb, thus not only providing good nutrition, but also acting as antidiabetic, hepatoprotective, antibacterial, antifungal, anti-inflammatory, anti-tumor, anti-cancer and anti-hypertensive, lowering cholesterol in adults and the aged (Fuglie, 1999, Kumar *et al.*, 2010, Sreelatha *et al.*, 2011). Although the value of *Moringa* is gaining more recognition, little has been done to introduce these benefits as food to most parts of the world. *Moringa* is still underutilized as a food, but is well-acceptable as medicine (Santhoshkumar *et al.*, 2013) and is also gaining acceptability in some localities for use in biofuel production (Kivevele *et al.*, 2011). Several studies show that *Moringa oleifera* can significantly improve the nutritional value of local diets, thus it has served as a food fortificant in amala (stiff dough), ogi (maize gruel, which is a Nigerian fermented meal consumed as a beverage) and bread (Oyeyinka and Oyeyinka, 2016). *Moringa oleifera* leaf powder (MOLP) has been used to improve biscuits, yogurt, cheese and soups (Ogunsina *et al.*, 2011, Oyeyinka and Oyeyinka, 2016). Similarly, MOLP has been investigated as a supplement in wheat bread at ratios of 1 to 5% and the results showed a significant improvement in nutritional composition. Furthermore, MOLP has been used to enhance

crackers (Sengev *et al.*, 2013). To this effect, several scholars have established that *Moringa* is valuable for improving the nutritional value of starch-based staple foods. In this way, it has good potential for alleviating micronutrient deficiency challenges.

In South Africa, the *Moringa* plant is mostly cultivated and used but mainly limited to medicinal, bio-fuel, industrial and then nutritional purposes (DAff, 2016). The provinces that are engaged in its production are those that are highly affected by poverty and malnutrition. The plant is cultivated in the Mpumalanga, Gauteng, Limpopo and KwaZulu-Natal provinces (Tshethlane, 2015, Govender, 2016). Locally, *Moringa* was introduced into rural communities in 2006 to combat malnutrition challenges by the Lammangata *Moringa* project, for remedying nutritional deficiency challenges but the plant appears to be more acceptable for non-food purposes (Pakade *et al.*, 2013, DAff, 2016). However, some part of the country in SA including the aforementioned provinces in South Africa are now adopting *Moringa* beyond medicinal plant to a nutrition dense plant. In South Africa, there is a limited number of studies conducted on incorporating *Moringa* in starch-based beverages such as the popular *mahewu*, which is a local maize-based, non-alcoholic beverage that is consumed for refreshment and as a filling food. However, since the *mahewu* is mostly made from white maize research in the literature maintains that maize-based food products are generally inadequate in micronutrients. Therefore, the aim of the present study is to evaluate the effects of incorporating MOLP on the nutritional value and consumer acceptability of a white maize-based fermented non-alcoholic drink (*mahewu* beverage). The study was conducted at Ntambanana, in the KwaZulu-Natal province of South Africa.

1.2 Significance of the Study

Mahewu is a maize meal-based drink. It is commonly consumed by people of all ages, from six months and above. Unfortunately, maize-based food products like the plain *mahewu* do not supply sufficient quantities of essential vitamins and minerals and protein that are vital in human and animal nutrition (Nuss and Tanumihardjo, 2010). In addition, maize meal lacks some of the nutrients that are found in maize because the bran and germ are removed during the milling process (Sarwar *et al.*, 2013). This leaves just the endosperm, which is constituted of carbohydrates (65 to 75%), proteins (6 to 12%), fat (1 to 5%) and traces of minerals and vitamins per dry weight. Inability regarding adequate intake of nutritious food is an intractable obstacle to economic growth and social progress, which are crucial in pursuing the achievement of most of the millennium development goal. Therefore, a comprehensive approach is needed

to combat such challenges. *Moringa Oleifera* is a highly nutritious plant that is climate resistant and requires less labor for its production compared to some plants. *Moringa oleifera* is not just limited to being medicinal plant, it has great potential to be used as a household food fortifying agent (Oyeyinka and Oyeyinka, 2016). Fortification of food or beverages with *Moringa* is an approach that could be cost-effective and efficient in supplementing local diets.

1.3 Problem Statement

Worldwide, malnutrition has been identified as a preventable health challenge, with its high prevalence reported in sub-Saharan African countries (Muthayya *et al.*, 2013b). Several studies show that its prevalence is high among the poorly resourced population groups, i.e. rural communities, where poverty, gender inequality, climate change, unemployment, high dependency on social grants and lack or limited knowledge about nutrition are prevalent. There is an inability to access safe sufficient and nutritious foods such as legumes, meat, milk, fresh fruit, and vegetables which contributes to malnutrition (Oxfam, 2014). Furthermore, over-reliance on cereal-based foods, such as beverages that are high in sugar, fats, and salt, either because of socio-economic status, is a contributor to malnutrition. *Mahewu* is made from maize meal and sugar. In Ntambanana it is consumed by people of all ages, including infants who are weaned from breast milk. However, consuming the drink as the main source of nutrients in a diet can lead to nutrient deficiencies.

The under-utilization of indigenous vegetables that are rich in essential protein, essential vitamins and minerals are considered a contributing factor to food and nutrition insecurity. It is a major hindrance in sub-Saharan Africa (SSA), as access to commercial food is limited for rural communities, although SSA region is rich in biodiversity (WHO, 2009). People are becoming conscious about their health and, thus, the trend of people opting for various food supplements is on the rise. *Moringa Oleifera* is an excellent food plant. It could be a cost-effective, and sustainable option for alleviating nutritional deficiencies in any diet that is inadequate in protein, vitamins, and minerals. In most communities, *Moringa Oleifera* is only known as a medicinal plant rather than a food item yet there are food that are staple to communities such as *mahewu* which lacking essential nutrient(Awobusuyi *et al.*, 2015b). Furthermore, to my knowledge there is no study in the literature on the acceptability of *Moringa Oleifera* powder as a fortifying agent of *mahewu* drink.

1.4 Aim of the Study

The general aim of the study was to investigate whether MOLP has nutritional enriching effects on *mahewu* and assess its consumer acceptability.

1.5 Specific Objectives

The following specific objectives of the study were identified:

- i. To determine the utilization of *mahewu* beverage in the municipality of Ntambanana.
- ii. To document the method of processing *Mahewu* used by the Ntambanana community.
- iii. To determine the nutritional composition of *Moringa Oleifera* leaf powder-supplemented *mahewu*.
- iv. To assess the consumer acceptability of MOLP-supplemented *mahewu* in Ntambanana.

1.6 Definition of Terms

- *Food security*

Food security refers to when all people at all times have the physical, social and economic ability to access safe and sufficient food that is able to meet their dietary needs for a productive and healthy life, without resorting to emergency food measures like scavenging, stealing or other coping strategies (FAO 1996, WHO 2016).

- *Food stability*

Food stability is the ability to obtain nutritious food over time without struggle or with little thought on where the next meal will come from (Saunders and Becker, 2015).

- *Food access*

Food access is the physical and economic ability of all categories of people, including full-time, part-time and smallholders farmers, to choose and purchase the food (Integrat, 2017).

- *Food availability*

Food availability is the supply of sufficient and quality of food via production, distribution, and exchange, including food aid (FAO, 2011)

- *Micronutrient*

Micronutrients are collective terms used for nutritive food chemical constituents (vitamins and minerals), which are needed in small amount by the body. Micronutrients work in cycle with macronutrients to sustain the body functioning and are vital to the

system, maintaining energy levels, metabolism, cellular function, physical and mental well-being (WHO, 2014).

- *Malnutrition*

Malnutrition is a broad terminology that is commonly used to describe undernutrition; however, it also describes over-nutrition. People are termed malnourished if their diet cannot provide adequate calories and good protein for growth and maintenance, or if prolonged illness or health issues incapacitate the individual from absorbing the food nutrients and utilizing it (undernutrition). The individual is equally malnourished if he or she consumes too many calories (over-nutrition). Furthermore, malnutrition results from inadequate nutrition due to the body's inability to utilize the nutrients from the food consumed (Dhakar *et al.*, 2011b, Walker and Schulze, 2008).

- *Whole food supplement*

Whole food supplement is a plant food enhancer for vitamin- and/or mineral-deficient foods, which is derived from raw, farm-fresh, organic and sustainably grown non-GMO ingredient (Popoola and Obembe, 2013)

- *Supplement*

A supplement is a synthetic tablet, syrup from medicine, natural food extract or powder from plants. It is any consumed substance that aims to complement the diet and provide additional nutrients, which might be missing or are insufficient in a particular food (Bazian, 2011).

- *Over-nutrition*

Over-nutrition is a form of malnutrition due to the overconsumption of nutrient foods, such that health is harmfully affected (Parks, 2015)

- *Under-nutrition*

Under-nutrition is a form of malnutrition - a condition resulting from not consuming enough or adequate essential nutrients through the varied food consumed by individuals. Nevertheless, it is not equal to under-eating, because it can occur despite over-eating (Parks, 2015).

- *Non-communicable diseases*

Non-communicable diseases are a health challenge that is not infectious. Non-communicable diseases are diseases of gradual progression, long duration and they are generally slow in being alleviated (Hofman, 2014).

- *Hidden hunger*

Hidden hunger is a nutritional deficiency caused by a nutrient imbalance in a diet (Muthayya *et al.*, 2013a).

1.7 *Moringa Oleifera* in Southern Africa

Moringa plant is noted for its drought-resistant nature, despite low rainfall, it can easily be cultivated in the backyard and can be used fresh as spinach when needed (Jideani and Diedericks, 2014). *Moringa* originates from the foothills of the Himalayan Mountains in India. However, information confirms that the plant was brought to South Africa about 160 years ago by Indian laborers (Pakade *et al.*, 2013). This implies that *Moringa* has been in South Africa for a very long time, although a study reports that South African farmers have shown some interest in the plant but only a few have started growing it as a food plant (Pakade *et al.*, 2013).

To tackle malnutrition challenges in the disadvantaged communities, *Moringa* plant was introduced to rural communities in 2006 by the Lammangata *Moringa* project (Lekgau, 2011). However, it is underutilized as a food in various localities of South Africa. Perhaps, this could be due to lack of proper awareness and knowledge on how this useful plant could be incorporated in various local foods/beverages, particularly in the rural areas where rich food sources of essential nutrient are less accessed. Nonetheless, *Moringa* was identified as a valuable resource for the Durban-based ‘*Moringa* 5000’ project (*Moringa* 5000, 2013). This project was launched in anticipation that the plant would gain popularity in South African communities. These communities include places where *Moringa* has made a footprint, like the Kloof Methodist Church, Hillcrest Embo Sethani, and eight other communities in the Valley of a 1000 Hills (*Moringa*5000, 2013). The project was aimed at educating people on how to cultivate and care for their own *Moringa* trees. The cost of each tree is subsidized by the community and local churches.

In this project, *Moringa* is being promoted as a long-term measure to alleviate the malnutrition challenges and for uplifting the livelihood of the dwellers in each community (Faithful to nature, 20/16). To this effect, South Africa has been rated as the largest supplier of high-quality seeds for *Moringa Oleifera* (*Moringaseed*, 2015). Though the seeds can be obtained from other countries such as Zambia, Northern Mozambique, and Malawi, *M. oleifera* seed production is on a larger scale in the village of: Tooseng in Limpopo Province, Free State, Mpumalanga and Gauteng in south Africa (Sosibo, 2011, Nicus, 2016). The fast-growing nature of the *Moringa*

tree and its high nutritional value have earned its reputation as a miracle plant (Fahey, 2005). Apart from the nutritional benefits, literature indicates that *Moringa* is perceived as an aesthetic plant and also a plant with a high economic value (Farinola *et al.*, 2014). Thus, *Moringa* can support the poor communities since it can be cultivated in the back yard with minimal attention (Ajayi *et al.*, 2014).

1.8 Organization of this Dissertation

Chapter one describes the background of the study, its problem statement and the motivation that led to the study. Chapter two provides a review of the literature with a focus on the prevalence of malnutrition, especially protein and micronutrient challenges in sub-Saharan Africa (SSA) and South Africa. In addition, it also highlights some documented fermented beverage, across the SSA countries, describing the raw materials and the mode of preparation and serving of the fermented beverages. The utilization of *mahewu* health benefits and deficiencies are also highlighted. The description of *Moringa*, its nutritional value and the uses as a food-based approach for food and nutrition security are reviewed. Chapter three describes Utilization of *mahewu*, a fermented maize meal-based beverage, in Ntambanana (KwaZulu-Natal, South Africa) and the potential of fortification with *Moringa oleifera*. Chapter four describes *Mahewu* a Non-Alcoholic Beverage: a documentation of the processing and making of the KwaZulu-Natal maize-based beverage. Chapter five details the Nutritional analysis and consumer acceptability of *Moringa Oleifera* leaf powder (MOPL)-supplemented *mahewu*. Chapter six presents conclusions, future research, and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Inadequate nutrition characterizes countries where food insecurity prevails and is common in sub-Saharan Africa (SSA). South Africa in SSA is known as a food secured country at the national level, however, at the household level, there is still food insecurity (Levinson and Bassett, 2007, Oxfam, 2014). A survey study South African National Health and Nutrition Examination Survey (SANHANES-1) by Shisana *et al.* (2014) reports that 28.3% of the South African population is at risk of hunger. Also, 26.0% of the population experiences hunger. This implies that more than one quarter of South Africans appear to be food insecure (SANHANES-1) (Shisana *et al.*, 2014). This review briefly describes malnutrition in sub-Saharan Africa, including South Africa, the uses of *Moringa Oleifera* and the nutritional benefits of the plant as an excellent plant to mitigate malnutrition challenges. Furthermore, the review also highlights the general perceptions of *Moringa Oleifera*, *mahewu* consumption and food-based approaches for addressing food and nutrition insecurity in SSA Southern Africa inclusive.

2.2 Malnutrition in Sub-Saharan Africa and in South Africa

Globally, malnutrition (especially micronutrient deficiency), is identified as one of the major health challenges. It is a problem commonly prevalent in low-income countries (Tsegay *et al.*, 2014). It is a major challenge that emerged in the year 1970s, despite all intervention strategies of alleviating micronutrient deficiency problem, it is still prevalent today, threatening many populations of the sub-Saharan African countries. Worldwide, it is still a topic that attracts keen consideration and study, and this might be due to its devastating impact on human health beginning from the onset of life and throughout adulthood (Ayalew, 2012). Information confirms that more than one micronutrient deficiency exists in many settings, especially in the rural communities and among the less-privileged in urban informal settings and societies of sub-Saharan African countries including South Africa (Ramakrishnan, 2002, von Grebmer *et al.*, 2014). Essential vitamin and mineral deficiencies, which include vitamin A, iron, iodine, zinc and folate, and now the B vitamins appear to be the most widely prevalent and studied (Muthayya *et al.*, 2013b). Worldwide, a significant percentage of people are micronutrient deficient, and the deficiencies remain a threat in many sub-Saharan African countries. It is reported that vitamin and mineral deficiency afflicts one-third of sub-Saharan Africa's population, affecting mental abilities, livelihoods and the economic prospects of many nations (WHO, 2014). According to the Muthayya (2013), out of the 195 countries of the world, the

estimate of the Disability Adjusted Life Years (DALYS) reported an alarmingly high prevalence of micronutrient deficiencies among 136 countries of the world, major prevalence are reported in countries of sub-Saharan Africa, alongside India and Afghanistan. The DALY rates per 100,000 people who suffer from micronutrient deficiencies are the highest in sub-Saharan African countries. It is reported that 36 countries of SSA attribute the figures to 90% of the world's stunted children. The deficiencies of micronutrients are accountable for 1.5-12% of the total DALYs where about 40.4% of the children in African regions are iodine deficient (Muthayya *et al.*, 2013b). Over 20% of children under five years of age suffer from deficiency of vitamin A and iron, and stunting is widespread in 37 countries. Forty percent of these children suffer from anemia, which is prevalent in most African countries. Fifty percent of school-aged children in thirteen countries are iodine deficient (Muthayya *et al.*, 2013b, WHO, 2014). South Africa is not an exception to these health challenges. It has been reported that South Africans food insecurity is at the household level (Oxfam, 2014) and also it is clearly stated that food security, hunger, and famine are directly related to poverty, which is one of the drivers of the aforementioned nutritional deficiency health problem (Ayalew, 2012). This implies that micronutrient malnutrition is inevitable where hunger and famine linger. Thus, from a global perspective, micronutrient deficiency is a food and nutrition insecurity determinant. Micronutrient deficiency has also been linked to factors such as poverty in South Africa. It is one consequence of unemployment and a high dependency rate on pension and social grants issues, which are indicators of limited economic power to access safe and nutritious food. This leads to the acquisition of food that is questionable or low in nutrition but which is cheaper than healthy alternatives.

The lack and inadequate consumption of fruits and varieties of green leafy vegetables among many people, especially those of low socio-economic status have been noted as one among the underlying contributors to the burden of contemporary non-communicable diseases. This results in high morbidity and mortality rates, especially the vulnerable groups, young children and women of reproductive age (Oyebode *et al.*, 2014). As a remedy to this situation, the World Health Organization (WHO) has recently been engaged in a strategy to promote the consumption of local fruits and vegetables. Both urban and rural communities are targeted (WHO, 2016). Therefore, modifying indigenous foods with available fruits and particularly leafy green vegetables that are rich in vitamins and minerals should be a key point for consideration and this is encouraged with respect to the wellbeing of a population. A daily intake of more than 400 g from various edible green leafy vegetables and fruits for a person

per day has been recommended to safeguard against micronutrient deficiency challenges (Smith and Eyzaguirre, 2007). Another study reports that the estimate of vegetable intake can be measured as up to “330 grams per day among children between aged 0-4 years, 480 grams among children aged 5-14 years and 600 grams per day in adults” (Nicus, 2016). This is besides the root vegetables that are rich in nutrients, such as sweet potatoes and carrots, and also leafy vegetables are known for their high concentration of essential minerals and vitamins.

2.3 *Moringa Oleifera*

2.3.1 General perceptions of *Moringa Oleifera*

Moringa Oleifera Lam is perceived as a multipurpose and exceptionally nutritious vegetable plant with a variety of potential uses in food. Therefore, it is used as a whole food supplement for the prevention of malnutrition challenges, and for industrial and medicinal purposes. This is evident in some African countries where people perceive *Moringa Oleifera* as a medicinal plant rather than a food plant (Mishra *et al.*, 2012). A study conducted in Nigeria, West Africa, examined the awareness and willingness to pay for *Moringa Oleifera* powder (Farinola *et al.*, 2014). The findings reported that *Moringa oleifera* is used as food in many meals and, therefore, it is currently gaining popularity because it has been known to have a high potential in alleviating human sufferings associated with (mal) nutrition. As such, quite a number of people in the same country are considering consuming *Moringa oleifera* leaves because of its high nutritional value, which consequently improve the food and nutrition security of the community at large. In that study, 85.3% of the responses showed some level of awareness on the health benefits of the *Moringa Oleifera* plant (Farinola *et al.*, 2014). Another study reported that *Moringa Oleifera* has significantly contributed positively to the health status of many individuals. However, the regular consumption level was low, as statistics showed that 22.7% of respondents consume *Moringa* daily, 58% monthly, while 45.3% were trying it for the first time (Farinola *et al.*, 2014). This implies that even though the plant is rich in nutrients, information still suggests a slow adoption of the plant as food in communities. This could be attributed to of lack of holistic knowledge on its uses in food preparation.

Apart from nutritional benefits, the literature indicates that *Moringa* is perceived as an aesthetic plant and also as a plant with a high economic value (Farinola *et al.*, 2014). This implies that *Moringa oleifera* can be cultivated for several purposes. This is an added advantage with respect to the disadvantages since it can be cultivated in the backyard garden of a household or

it can even be used as fencing around the house for providing natural aesthetic value; as well as providing well-being through improved nutrition and better livelihoods of smallholder farmers (Ajayi *et al.*, 2014). This substantiates the testimony from Tooseng in South Africa, which attests that *Moringa Oleifera* is a ‘miracle’ tree and that is changing the nutritional status of communities struggling with food insecurity and malnutrition issues, and also improving livelihoods (Sosibo, 2011).

When people are food secure, then their food and nutrition status is more certain. Commercial growers are making a lot of money from this fast-growing plant, thus, it is perceived that it could be a reliable source of livelihood among the marginalized in many communities. Gender inequality and level of education issues are perceived to be a problem in achieving higher levels of *Moringa* propagation. One study declares that gender disparity is one reason for the gaps that limit the gains of innovations on *Moringa Oleifera*. It also appears as one factor limiting the acceptance of innovations and propagation of the plant among rural communities (Torimiro *et al.*, 2013, Oyekale *et al.*, 2015). If there is an innovation generated in any community towards this type of exercise, there should be proper screening to ensure that there is no upset by delegating economic power balance between men and women in the agricultural sector or the widening of gender inequalities. Furthermore, policies that encourage literacy in women, and nutrition education as well as access to innovations and farm labor, especially amongst the disadvantaged, who are indispensable in improving social-cultural perceptions and adoption of *Moringa*, are required (Oyekale *et al.*, 2015).

Not all people are aware of the benefits of *Moringa oleifera*, and few people appears to have interest in its utilization as a food. The literature identifies factors affecting the acceptance of *Moringa* to include education, age, and individual food preference for other vegetables. Although the level of awareness about *Moringa* appears high in some studies, consumers showed a preference for other vegetables (Oyekale *et al.*, 2015). This suggests that more work should be undertaken to sensitize people into have a positive mindset towards foods that are rich in nutrients through an effective method of information disseminations of knowledge. This might help in stimulating consumer acceptance of *Moringa* and, to an extent, alleviate many nutritional health challenges.

2.3.2 Uses of *Moringa Oleifera*

Several studies confirm that fresh leaves of *Moringa Oleifera* are used just like any other leafy green vegetables (Jideani and Diedericks, 2014). It can be added to soups, sauces as food condiments, salads, vegetable curries, used for pickles and for seasonings, and it is also added to porridge or beverages of any choice. The leaves can be eaten in a fresh condition but only in a small quantity, and they can be processed locally and stored in an air-tight container as dried powder at room temperature for many months, yet retaining the nutritional value (Farinola *et al.*, 2014). Furthermore *Moringa oleifera* can also be added to any less nutrient-dense meals (Ogbe and Affiku, 2011). The flowers can be cooked and either mixed with other foods or fried in batter, while the seeds, which are often referred to as peas, can be used when still tender as at the time they appear as green peas in foods. When the seeds get mature, they become toughened and hardened. At this point, the mature seeds taste bitter and can be processed to yield about 38 – 40% of edible oil (Jideani and Diedericks, 2014), which is a clear, sweet, odorless and never becomes rancid oil. When compared with other oils, the properties of *Moringa* oil can be likened to that of olive oil. *Moringa* seeds have also been used to manufacture perfumes and aromatherapy oils. When the seed gets harder it can be powdered and it is used for treating water in the water industry or in localities where the water has a lot of impurities because it is known to coagulate solid materials and it also removes (90 – 99%) bacteria in water (Mumuni and Elizabeth O, 2013). The stiff root has been used as a substitute for horseradish. However, this is now discouraged, because the root is known to have alkaloids, especially moriginine and the bacteriocide, spirochin, both of which are poisonous. However, the older roots and the root bark are good sources of tanning agents (Fahey, 2005, Jideani and Diedericks, 2014). *Moringa oleifera* properties are used in traditional medicine to control disorders in the human circulatory system. Consumption of *Moringa Oleifera* has been noted for promoting healthy hair, by improving the physical appearance to a great extent. *Moringa Oleifera* has been reported to possess anti-aging properties. The seed extract is popular in the cosmetics industry because of its therapeutic and purifying properties on the skin (FitLife, 2016). More studies are ongoing on the uses and most beneficial aspects of *Moringa Oleifera* and perhaps many more benefits are yet to be discovered.

2.3.3 Nutritional benefits of *Moringa Oleifera*

The easy access to *Moringa* leaves and leaf powder makes it a cost effective, sustainable approach to an intervention strategy to addressing malnutrition challenges. A study reports that

Moringa leaf powder has been used to prevent/alleviate malnutrition in pregnant, lactating women and their children in southwestern Senegal (Dhakar *et al.*, 2011a). The same study maintains that 600 malnourished infants are treated every year and the results show that the children maintain or increase their body weight which improves their overall health. Furthermore, the study shows that the pregnant women recover from anemia, have babies with higher birth weights and lactating women increase their production of milk (Dhakar *et al.*, 2011b). *Moringa Oleifera* is one of the excellent promising plants that have the potential to increase the intake of some essential nutrients (Vitamins and minerals) from the human diet. It also contains health-promoting phytochemicals (Okiki *et al.*, 2015). The plant is dense in essential micronutrients that support the development and functioning of the human body systems. Thus it has long been promoted and advocated as an excellent source of vitamins, quality protein (amino acids), iron, potassium, and calcium. The vegetable is considered to be rich in carotenoids, antioxidants and other phytochemicals (Jed and Fahey, 2005, Jideani and Diedericks, 2014). In addition, *Moringa Oleifera* possesses antitumor, antipyretic, antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal properties (Anwar *et al.*, 2007). A high intake of antioxidants from dietary sources such as *Moringa* is very important for the removal of free radicals from our bodies. The natural antioxidants component of *Moringa oleifera* makes it a better source of antioxidants than synthetic products because natural antioxidants are less toxic and are more potent in addressing nutritional health challenges (Pakade *et al.*, 2013).

The health benefits of *Moringa* cannot be overemphasized. All parts of the plant have the potential for use in lowering sugar level in the case of high blood sugar challenges. *Moringa* has been promoted as a traditional medicine for many centuries (Jed and Fahey, 2005, Sreepada Hegde and Hegde, 2015). The leaves, pods, seeds, gums, bark, and flowers of *Moringa* have been used in more than 80 countries (Ahmad *et al.*, 2014). It has been used in Pakistan to cure mineral and vitamin deficiencies, to support a healthy cardiovascular system, to promote normal blood glucose levels. This, therefore, reduces malignancy, provides excellent support to the body's anti-inflammatory mechanisms, alleviates anemic blood challenges and supports the immune system. *Moringa* has a special potential for use in intervention programs treating avitaminosis (the vitamin A deficiency that causes 70% of childhood blindness and diseases such as scurvy, beriberi or pellagra), which is caused by a deficiency in one or more essential vitamins. By implication, the high vitamin A content of *Moringa Oleifera* (Table 2.1) is

important for improving eyesight (Jideani and Diedericks, 2014). Furthermore, consumption of *Moringa Oleifera* lowers blood lipids, thereby reducing the occurrences of diseases linked with the damage of the coronary arteries. *Moringa* is also good for livestock, fisheries and is efficacious in the prevention and treating of various types of livestock diseases. In Table 2.1, the results of an analysis of the nutritional value of *Moringa Oleifera* leaf powder are documented. It has been found promising for tackling protein and energy malnutrition hence its nutritional value is outline below.

Table 2. 1: The nutritional value of *Moringa Oleifera* leaf powder

Nutrient component	Nutrient content (100 g ⁻¹)
Moisture (%)	7.5
Calories	205
Protein (g)	27.1
Fat (g)	2.3
Carbohydrate (g)	38.2
Fiber (g)	19.2
Minerals (g)	-
Ca (mg)	2,003
Mg (mg)	368
P (mg)	204
K (mg)	1,324
Cu (mg)	0.57
Fe (mg)	28.2
S (mg)	870
Oxalic acid (mg)	1.60
Vitamin A - B carotene (mg)	16.3
Vitamin B -choline (mg)	-
Vitamin B1 -thiamine (mg)	2.64
Vitamin B2 -riboflavin (mg)	20.5
Vitamin B3 -nicotinic acid (mg)	8.2
Vitamin C -ascorbic acid (mg)	17.3
Vitamin E -tocopherol acetate (mg)	113
Arginine (g/16 g N)	1.33%
Histidine (g/16 g N)	0.61%
Lysine (g/16 g N)	1.32%
Tryptophan (g/16 g N)	0.43%
Phenylalanine (g/16 g N)	1.39%
Methionine (g/16 g N)	0.35%
Threonine (g/16 g N)	1.19%
Leucine (g/16 g N)	1.95%
Isoleucine (g/16 g N)	0.83%
Valine (g/16 g N)	1

(Fuglie, 2006-20012)

2.3.4 *Moringa Oleifera* in staple foods

Failure to meet the minimum daily dietary protein and micronutrient requirements is one of the key indicators of food insecurity. Studies documented that the use of *Moringa oleifera* dates back to 150 B.C. (Cambodia, 2016). The nutritional benefits of the plant and especially the leaves are undeniable in staple-based food products. The leaves of *Moringa oleifera* contain seven times the vitamin C present in oranges, four times the calcium present in milk, four times the vitamin A present in carrots, three times the potassium present in bananas and two times the protein present in yogurt (Table 2.2).

Table 2. 2: Nutrient value of MOLP relative to popular food sources

Food	Nutrient	Nutrient content per 100 mg and g	Nutrient content in MOLP relative to this food
Carrots	β -Carotene, a precursor for vitamin A	39.6 mg (Sharma <i>et al.</i> , 2012)	10 times
Cow milk	Calcium	122 mg (Pereira, 2014)	17 times
Bananas	Potassium	422.44mg (Mateljan, 2018)	15 times
Spinach	Iron	4.8% (Singh <i>et al.</i> , 2001)	25 times
Whole milk Yogurt	Protein	8.6g (Mckinley, 2005)	9 times

(Mishra *et al.*, 2012, Gopalakrishnan *et al.*, 2016)

Moringa oleifera leaf powder (MOLP) has been used to enhance the nutritional value of many food products. In human nutrition, it has been explored in the development of amala, a stiff dough that is popular with Nigerians as a staple food (Karim *et al.*, 2015). Furthermore, 10% and 15% of *Moringa* was incorporated in a maize gruel (Abioye and MO, 2015), and *Moringa Oleifera* has also been used for enhancing crackers which are a nutritious/convenient means of consuming a staple food or cereal grain. However, it is reported that the product tasted grassy (Manaois *et al.*, 2013). Another study in Ghana worked on introducing MOLP into a school lunch menu. The study showed a positive consumer acceptability than other vegetables introduced in the menu (Glover-Amengor *et al.*, 2017). It is documented that the optimum dose of *Moringa* consumption is 29 mg per kg of body weight (Axe, 2016). Some studies maintain that one rounded tablespoon of MOLP is equal to 8 g, which makes up about 14% of the protein, 40% of the calcium, 23% of the iron, and nearly all the vitamin A needed for a child aged 1-3

years is embedded in 8 g of MOLP (Price, 1985b, Mishra *et al.*, 2012). It is also reported that six rounded spoonful of MOLP powder are able to supply nearly all of a woman's daily iron and calcium needs during pregnancy and breastfeeding. One rounded tablespoon of MOLP, added to the child's food three times daily, will meet the recommended dietary needs of a child aged 1-3 years (Price, 1985a, Mishra *et al.*, 2012). Although MOLP is a nutrient dense plant, its acceptance in some localities is still on the rise as it is reported that it taste bitter, grassy and has a raw and leafy after taste (Nour and Ibrahim, 2016).

2.3.5 Heat treatment of *Moringa* leafy powder before adding to mahewu

According to Sallau (2012), the majority of the plant-based foods including *Moringa Oleifera*, contain some amount of anti-nutritional factors (Sallau *et al.*, 2012). The most common anti-nutrient factors in such foods are tannin, phytates, protease and calcium oxalate, saponins (Healtheir, 2017). An additional study maintains that *Moringa* contains some concentration of polyphenols such as saponins. Moreover, it is identified that dry vegetables also contain more concentration of phytates and oxalate than fresh vegetables (Aregheore, 2012, Badmos and Ajiboye, 2012). Further, polyphenol and saponins including tannin are noted for their bitter taste and also they are reported as being present in *Moringa Oleifera* (Sallau *et al.*, 2012). Another study reports a significant concentration (3.12 mg/g) of condensed tannins in dry leaves of *Moringa Oleifera* (Moyo *et al.*, 2011).

It is reported that anti-nutritional factors are not always unhealthy (Khokhar and Apenten, 2003), implying that anti-nutrients like tannins might have some health benefits. Thus, since most plant-based food sources contain some amount of anti-nutrient factors, which are present and they might even be significant in dry vegetables such as MOLP. Boiling as one of the food processing method have been used and was used in this present study as the high sensory content of these anti-nutrient factors is noted to have a negative effect on the bioavailability, maximum acceptance and utilization of the main nutrients that are of benefit in the food.

The effects of food processing methods such as simmering, blanching and boiling of some anti-nutritional contents of *Moringa Oleifera* leaves have been investigated and it was reported that boiling has a significant effect, which reduces the cyanide content by 88.1% (Sallau *et al.*, 2012). Thus, in this study, *Moringa* was subjected to heat treatment (boiled) to 100 °C before being added to the *mahewu*, so as to suppress the raw leafy taste, and perhaps reduce the effects of other aforementioned sensory attributes of *Moringa Oleifera* food products with the aim of enhancing its consumer acceptability. It has been noted that dried *Moringa* leaves can be used

in food preparations such as sauces and still retain its significant nutritional value. A study conducted in Ghana indicates a positive acceptability of *Moringa* in some local dishes. Furthermore, in Nigeria, MOLP has been added to sauces and other foods such as *ogi* maize gruel, bread, and biscuits (Glover-Amengor *et al.*, 2016), hence the justification for heat-treating the MOLP before adding to the *mahewu*.

However, other studies and observations confirm consumer acceptability of foods containing MOLP. Empirically, it is identified that adding MOLP to food alters the usual taste which makes the food have an aftertaste that is raw leafy, pungent, grassy and bitter (Nour and Ibrahim, 2016, Ntila *et al.*, 2018). Notwithstanding, when trying to supplement food, it is not good to improve the nutritional value of the food at the expense of the sensory properties (taste in particular), as this plays a large role in determining the consumer acceptability for food. *Moringa* has been added to other cereal-based foods such as in wheat, bread, *ogi*, maize, gruel, beverages (Sengev *et al.*, 2013) and it has also been added to cookies and *ogi* (Olorode *et al.*, 2013, Oyeyinka and Oyeyinka, 2016) but not to *mahewu*. Thus, there is scarce or limited information on the addition of *Moringa Oleifera* in *mahewu* beverage.

2.4 Mahewu: A maize-based lactic acid fermented beverage

Mahewu is a non-alcoholic beverage that is made from maize meal porridge that undergoes a lactic acid fermentation process (Awobusuyi *et al.*, 2015b). Food fermentation is an old technology in food processing, which dates back to 6000 years ago. Traditionally, this technology has been known to provide desirable sensory and functional properties in cereal based food, which includes shelf life and the best organoleptic properties (Kohajdová, 2014). It is produced through a metabolic process of deriving energy from an organic compound without the involvement of an exogenous oxidizing agent, and also involves the degradation of carbohydrate by microorganisms (Arslan and Erbas, 2016). The most common group of bacteria involved in food fermentation is *Lactobacillaceae*, which produces lactic acid from the carbohydrates. *Lactobacillaceae* are the most common microorganisms found in *mahewu* and other naturally fermented food products (Yeğin and Üren, 2008). The traditional fermentation of cereal-based food has been practiced before and is still being used in many countries such as Asia, sub-Saharan African countries, and some Arabian countries as well (Arıcı and Daglioglu, 2002). The preparation of many indigenous fermented foods and beverages remains a valuable domestic skill and source of livelihood, especially among the disadvantaged. Beverages that are *mahewu*-like are predominantly produced at the household level. Although they are now available commercially, consumers still prefer homemade products (Blandino *et al.*, 2003).

2.4.1 Mahewu consumption in southern Africa

Mahewu is a cereal-based beverage made from maize, although it can also be made from sorghum. It is popularly consumed in South Africa, having various names. In Zulu, it is known as ‘*mahewu*’; the Xhosas call it ‘*amarehwu*’; the Swazis call it ‘*emahewu*’; the Pedis call it ‘*Metogo*’; the Tsuthus call it ‘*Machleu*’, while the Vendas call it ‘*Maphulo*’ (Katongole, 2008). It is noteworthy that apart from the fact that this beverage is a refreshing beverage in the local communities, it is now also used as a filling beverage. Some people consume it as food to satisfy hunger regardless of age. In this part of sub-Saharan Africa, it is popularly consumed for dual purposes among most rural localities and also among the less privileged in urban settings as well as those that like the unique taste of the beverage. However, it has been noted that its nutritional value is inferior due to a low protein content, and a deficiency of certain essential amino acids, essential vitamins, and minerals (Chavan *et al.*, 1989, Awobusuyi *et al.*, 2015b). Thus it suggests that this could be one among other factors contributing to the high

occurrence of health-related challenges of micronutrient deficiencies among the regular consumers, who are the disadvantaged in the rural population who frequently consume *mahewu* without adding a variety of nutrient-dense food sources. Therefore, frequent consumption of local or unfortified homemade *mahewu*, without the consumption of other food sources such as vegetables and fruits, increases the chances of being predisposed to health challenges related to nutrient deficiencies (Chavan *et al.*, 1989, Awobusuyi, 2015).

2.4.2 Preparation of mahewu

The preparation of *mahewu* beverage involves lactic acid fermentation of thin a slurry maize meal porridge (Awobusuyi *et al.*, 2015). The porridge is obtained by mixing a portion of maize meal in cold water and adding it to a quantity of boiling water depending on the final product desired. After mixing the maize meal into the boiling water, stirring continues until a thin maize consistency is obtained. When the porridge is well cooked, cold water is added to loosen the viscosity there after, sugar is mostly added and is allowed to ferment. The porridge is poured into a plastic container, which is half covered and placed in a dark warm place to ferment. The fermentation is stopped by putting the porridge into refrigeration. Then, it is finally served chilled and is mostly consumed as a refreshing drink (Awobusuyi *et al.*, 2015b). One good property of *mahewu* is that it increases in volume when cold water is added to it while still retaining its refreshing sour taste, especially when sugar is added. Thus, this might be one of the reasons why it is regarded as an economical, refreshing drink yet is still a filling beverage for the low-income population in urban settings and the poor in remote rural communities (Schweigart and Fellingham, 1963). Although the addition of water might increase the volume of the *mahewu*, it can be agreed that as water is added to the beverage for any purpose, while the sour but refreshing taste is still maintained, the nutritional density might equally be reducing. Thus, the need for enhancing the *mahewu* beverage with other nutrients after adding water before consumption, such as enhancing it through fortification/supplementation, might be helpful in achieving the food and nutrition security of the consumers. Most African countries still consume *mahewu* or *mahewu*-like fermented food products, although using different raw materials and different methods of preparation. Below, are some African lactic acid fermented beverages, their ingredients (raw material used), preparation and the manner in which the beverages are served?

Table 2. 3: Reported raw materials, the mode of preparation and serving of mahewu and other fermented beverages, across the SSA countries

Country	Ingredient for <i>Mahewu</i> and other fermented	Preparation	How it is served and consumed
Southern Africa <i>mahewu</i>	<ul style="list-style-type: none"> • Maize meal • Water • Malted cereal (optional) • Sugar to taste 	<ul style="list-style-type: none"> • Mix the maize meal thoroughly with water. • Cook until well gelatinized (a thin Starchy porridge consistency is obtained). • Keep at room temperature (25–30C) to cool. Then allow to ferment for 2-3 days. 	It is slurry in texture and is served chilled.
Nigeria <ul style="list-style-type: none"> • Ogi and Akamu (also called pap) • Nigerian Gruel (Commonly called Kunuzaki). 	<ul style="list-style-type: none"> • Maize, sorghum or millet are used, sugar is optional • Maize, millet, and sorghum sugar 	<ul style="list-style-type: none"> • The cereal is steeped, soaked for 1-2 days, and milled into the dough. Water is added so that it can be sieved freely using a fine sieve. The filtrate is allowed to settle and a creamy texture is obtained. The texture is collected into a bowl. Water is boiled and is poured over the filtrate depending on the consistency desired, and sugar is added. (Panesar and Marwaha, 2013). In ogi preparation, a mix of yeast and Lactobacillus is involved in the fermentation process, thus it tastes sour. • The cereal is steeped in water for one day. It is then milled into a paste. Water is boiled and then poured over it while stirring until it is thickened. It is then left to cool to a lukewarm temperature. Starter made from germinated rice or sweet potatoes is added as a natural culture which speeds up the fermentation process. It is left to stand for 24 hours. Finally, water is added, and it is sieved using a fine sieve. 	<p>(1) Ogi and akamu are creamy, served hot as breakfast alongside with bean pudding or bean fritters</p> <p>(2) The consistency of gruel is watery, unlike ogi and it is served chilled in liquid form as a refreshing drink.</p>
Ghana Kenkey	Maize, sorghum or millet, maize	<ul style="list-style-type: none"> • Maize is steeped for 24-48 hours and milled into a dough, moistening with water. It is kept fermenting for 2-3 days. 1/3 of the dough is precooked, and the precooked dough mixed with the remaining dough. It is packaged in plantain leaves and then cooked for 3 hours (Halm <i>et al.</i>, 1996). 	It is usually served with pepper sauce and fried fish or soup, stew.
East Africa Uji	Maize, sorghum, millet	<ul style="list-style-type: none"> • The maize is milled mixed with 30% of water to a slurry consistency. It is kept at ambient temperature to ferment for 2-5 days, and the remaining water is added to dilute. It is then boiled, and sugar is added to taste (Panesar and Marwaha, 2013). 	It is sold hot to factory and construction site workers by small-scale producers in Kenya.

Ethiopia Injera	Sorghum and a starter are saved in batter form from the last of a batch of injera	<ul style="list-style-type: none"> This is made by mixing the milled sorghum with water in a ratio of 1:2, followed by the addition of a traditional starter called ersho. A fluid saved from the previously fermented dough is mixed with 16% by weight of flour and left to ferment for 3 days at an ambient temperature. The fermented dough is kneaded and thinned into a batter by adding a quantity of water that is equal to the weight of flour. The thin batter is left to ferment for 2 hours prior to cooking in a hot injera clay pot. A small amount of batter is saved for a starter for the next batch of injera. The micro-organisms involved in injera are <i>candida guilliermondii</i> and <i>Lactobacillus bulgaricus</i>, and some <i>Lactobacillus</i> species (Panesar and Marwaha, 2013). 	Served hot
Benin and Togo	Dehulled Maize	<ul style="list-style-type: none"> This is done by cleaning, washing and decorating maize kernel. The endosperm is moistened and milled, and water is added to the flour to produce a dough consistency. It is then fermented at an ambient temperature for 2-3 days, at approximately 25-30 °C. LAB <i>Lactobacillus</i> and yeast are the bacteria involved in the fermentation process. The PH of the fermented mawe is 3.9 for commercial mawe while homemade mawe has a PH value of 4.2. Color, fineness and acidity are the major criteria for a quality mawe (Steinkraus, 1995). 	It is served cold
<i>Boza</i> is a non-alcoholic beverage that is consumed daily in Bulgaria, Albania, Turkey, and Romania	Wheat, rye, millet, maize and other cereals mixed with sugar or saccharin	<ul style="list-style-type: none"> Boza can be prepared by milling cereals, it is mixed in water, and then cooked in an open or steam-jacketed boiler. The gruel is cooled and strained to remove the bran and hull. Sugar is added and allowed to ferment at 30 °C for 24 hours by back-slopping or use of sourdough and/or by adding yogurt starter cultures. Fermented boza is then cooled to a chilled temperature, it is distributed into 1L plastic bottles to be consumed within 3-5 days. Boza is popularly accepted in the countries referred to above due to its pleasant taste, flavor and nutritional value. The fermentation process involves spontaneous fermentation or Lactic acid fermentation. 	It is served chilled

In summary, it can be observed that most if not all of the beverages identified are cereal-based. In addition, they all undergo lactic acid (*Lactobacillus bulgaricus*) fermentation and they might not exhibit a pronounced difference in consistency. They are also fermented at similar temperatures and they take roughly the same amount of time for fermentation processes. *Mahewu*, whether locally made or commercially made, is a beverage that is widely acceptable by many, which indicates that it has a desirable taste and is appreciated by the consumers. However, with the addition of *Moringa* to *mahewu* in this study, such desirability might be compromised. Which in a further study this may necessitate the addition of artificial flavorings and colorings so as to make supplemented *mahewu* beverage retain its desirability and acceptability level.

2.4.3 Commercial mahewu in southern Africa

Most popular and commercially available *mahewu* content are usually white because they are made from the dehuulled white mealy maize, which has undergone some level of processing. Furthermore, the commercial product are mostly prepared such that it is attractive to its consumers, for marketability sake, since the color is usually being considered. This underscores the fact that white maize is often more preferred and acceptable than yellow maize (Nuss and Tanumihardjo, 2010).

In southern Africa, the commercialized *mahewu* products are noted in Figure 2.1 and are readily available in shopping malls. The commercial *mahewu* is marketable because fermentation is one way of diversifying the diet of consumers. It is an old technique of preserving food, which contains probiotics. This attribute increases the demand for functional foods which are being encouraged today. Some people consume it as a meal substitute (Zazoo, 2016). Apart from the locally made *mahewu*, the commonly available product in South African malls is Mnandi *mahewu* and it is the largest commercially accepted *mahewu* brand in the region of KwaZulu-Natal, South Africa. This maize-based fermented food drink has been trusted as a source of energy in the Zulu culture for years and especially among the low-income population. It is available in three flavors: pineapple, banana and creamy (RCL Foods, 2016). It is also believed that Mnandi *mahewu* is an affordable, filling and refreshing drink. Moreover, it is identified as an option that remains true to its cultural roots. This product appears to be preferred because the producers tend to maintain the great taste that some customers expect.



Figure 2. 1: Samples of commercial mahewu beverage in South Africa (Ejozi, 2009)

Colors of a homemade *mahewu*

There is limited documentation on a specific color of homemade *mahewu*. However, the raw material used for fermentation (either maize, millet or sorghum) determines the natural color of the finished product, except when synthetic color are added. Below are some fermented cereal beverages in their natural color.



Figure 2. 2: Mahewu from Sorghum (The African pot nutrition, 2015)



Figure 2. 3: Mahewu from maize (The African pot nutrition, 2015)



Figure 2. 4: Mahewu from millet source (Rubie, 2013)

2. 4. Fermented foods and food security

Food security happens when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996 Vice, 2013). Fermented foods play a vital role in ensuring the food security of millions of people around the world and in South Africa, particularly for those that are marginalized and vulnerable groups (Chelule *et al.*, 2015). As aforementioned, *mahewu* is a common beverage that requires less time in preparation, therefore, it makes it easily accessible to the common person. In South Africa, it is a beverage that is consumed as a refreshing drink in the summer months and as a filling food. Thus, this seems to supply the consumers with most of their macronutrients and micronutrients (Marshall and Mejia, 2011). (Marshall and Mejia, 2011). Fermented food without nutrient-dense sources of food, stands to supply little of micronutrients to it and by implication the consumer nutritional security is still incomplete. Thus, if *mahewu* is to be consumed as a filling food, its nutritional value must be enhanced, otherwise, it remains devoid of essential nutrients. Hence, there is a need to supplement *mahewu* as presented in this study with nutrient rich sources of the essential nutrient such as *Moringa oleifera* plant.

2.5 Food-based approach for addressing food and nutrition insecurity

The food-based approach has been a measure that has been used in achieving food security as well as food and nutrition security. It is seen as a practical strategy that is aimed at meeting the nutritional needs of consumers by increasing the availability, accessibility, and utilization of nutritious foods through agriculture, small production, fortification and bio-fortification (Thompson and Amoroso, 2014). Due to the escalating burden of human suffering that is prevalent among the under-resourced communities, food and nutrition security of consumers is identified to be a key point that is worthy of consideration. Therefore, food-based intervention has been studied and it is necessary for poorly-resourced populations, where the prevalence of micronutrient deficiencies and its hazards are high, but with more focus on the diet of young children and mothers as the most vulnerable group. It is identified that this approach can easily be achieved by changes in a conscious selection of foods that are of nutrient-dense quality. This situation can be achieved by adapting to improved nutritional patterns and traditional household methods for preparing, processing and utilization of foods with a high content of nutrients throughout the year (Thompson and Amoroso, 2010, Thompson and Amoroso, 2014). Also, besides the relegation of the private sector which reflects on the approach as belonging to the agricultural domain and nutritional enhancement, a food-based approach leads to other

objectives such as generating income and some means of livelihood, which would make this approach most attractive, beneficial, and open to solving other life challenges. This will help to achieve the desired sustainability of nutritional intervention and would, consequently, ensure food and nutrition security. This has been noted and considered to be achieved through many strategies which include: dietary diversification, fortification, bio-fortification modification and supplementation(Thompson and Amoroso, 2010).

2.5.1 Dietary diversification

Several studies have established the fact that the consumption of diets with a higher dietary diversity enhances adequate micronutrient intake from the variety of that diet (Thompson and Amoroso, 2014). Therefore, dietary diversification involves a change or modification in the pattern of selecting foods and the methods for preparing and processing of household foods, with the aim of enhancing availability, access and increased consumption of foods that are enriched with adequate nutrient necessary for immunity, growth and proper development of both humans and animals (Thompson and Amoroso, 2010). This approach invariably includes evaluating the dietary consumption, expanding the land and varying the food production, with a special focus on those products such as the *Moringa* plant that are resilient to drastic climatic change. It also encompasses improving food processing and preserving, storage and improving the methods of food preparation. Notwithstanding, the effectiveness of this strategy will depend on a nutrition education program by creating more awareness about foods that are rich in the nutrients that are needed as a support in rural places, because the staple diets in most developing countries do not only lack one micronutrient, but a wide range of micronutrients(Thompson and Amoroso, 2014). Thus, strategies should consciously be aimed at enhancing the nutritional quality, with more attention on the bioavailability of all vitamins and minerals, as one intervention strategy that appears capable of combating micronutrient deficiencies. Beyond the dietary diversification practices, it involves the manipulation of staple cereal and household diets with a goal of adding variety in order to enhance the nutritional value (or micronutrients) of the foods(Gibson and Hotz, 2001).

2.5.2 Food fortification

Food fortification is practiced consciously to increase the content of essential micronutrient in vitamins and minerals (including trace elements) at a higher level than that found in the original state of the food, with the aim of improving the nutritional quality of the food and providing the

public with good health benefits at are void of health hazards (Dary and Mora, 2002). The common fortified foods include staple product such as rice, maize flour, wheat flour, salt, sugar, vegetable oil, and a host of other food products. However, it is also necessary to have access to, also to use, fortificants that can be absorbed and yet do not affect the sensory properties of foods (Allen *et al.*, 2006). Thus, edible leafy vegetables that are rich in essential vitamins and minerals can be added to foods as fortificants in order to ensure that individual nutritional requirements are met. In order to make this strategy effective and to achieve the goal of food security and nutrition it would be better implemented together with other strategies, including diet diversification and supplementation.

2.5.3 Constraints of food fortification

There are some substantial technical barriers to food fortification. They include adverse effects on the sensory qualities of food nutrients, challenges of nutrient interactions, poor bioavailability of some fortificants and the difficulty of fortifying some staple foods such as rice. Also, fortification can only be successfully carried out through partnerships between government industries and the consumer. Thus, there is a need to really evaluate the successes and failures, especially in the rural communities (Darnton-Hill and Nalubola, 2002). Food fortification programs are aimed at targeting large populations through the wide distribution of foods that are prepared industrially and which are for public consumption. There is little infrastructure, purchasing power, or access to markets and healthcare systems for the success of this intervention (Mayer *et al.*, 2008)

2.5.4 Bio-fortification

Bio-fortification is another process of enhancing nutritional quality, such as making the right proportion of the correct micronutrients in food crops through improved agronomical practices of conventional plant breeding or modern biotechnology such as genetic modification. Bio-fortification aims at increasing the nutrient content level in staple crops during cultivation. The main approaches to bio-fortification are agronomic practices, conventional plant breeding, and genetic modifications involving gene insertions or induced mutations (Thompson and Amoroso, 2010).

2.5.5 Constraints of bio-fortification

Micronutrients are sometimes unevenly distributed in the plant which could pose a danger to both plants and humans. To my knowledge, there appears to be limited infrastructure, purchasing power, or access to markets and healthcare systems for the success of people living in remote rural areas. The target of breeding in bio-fortification is set to achieve measurable health impacts as determined by nutritionists, and some consumers tend not to like bio-fortified food crops, thus there are constraints regarding bio-fortified foods.

2.5.6 Home fortification

The economic development of any successful nation depends on the health status of the population. The non-communicable health problem is prevalent in many settings, especially in underdeveloped countries. The amassed losses to the South African gross domestic product (GDP) between 2006 and 2015 from diabetes, stroke and coronary cardiovascular disease alone are estimated to cost the country US\$1.88 billion, (R 25.50265 billion) . Micronutrient deficiency of vitamin A, iron zinc and iodine are other disturbing non-communicable diseases (NCDs). There is a decreasing premature mortality through NCDs which is prioritized with the most importance as a developmental agenda (Alleyne *et al.*, 2013, Dora *et al.*, 2015). The privileged in many societies are becoming more careful regarding their diet, thus, there is a trend and an increase in conscious consumption of nutritious food, leading to the home fortification of various foods that is lacking in some nutrients. Home fortification is a method that has practically been used with a deliberate aim of enhancing the nutritional content of a particular food. Although fortification has been used for the large population it can be practiced at the household level. Home fortification, therefore, is a means by which the essential nutrients (micronutrients) lacking in a food are enhanced during food preparation using bioavailable food sources at the household level (Tulchinsky, 2015).

2.5.7 Home supplementation

Globally and in sub-Saharan Africa, including South Africa, challenges of nutrient deficiencies, such as Vitamin A, iron and iodine and zinc deficiency affect many populations, leaving those populations with pains that disrupt their potential and they are reported as one major factors adding to the huge burden of diseases and death (Tulchinsky, 2010). Other micronutrients of concern are B Vitamins and Vitamin C (Herrador *et al.*, 2014). This has led to home supplementation of some foods at the household level. Home supplementation of food is the

use of available bioavailable food sources such as vegetables and fruits to supplement the nutrients that are lacking in most foods, such as those that are staple based at the household level.

Currently, people are more conscious of their health and they want to live healthier lives, thus, the trend of diverse food supplements on the market shelves seems to be increasing, with examples such as pumpkin seed powder, almond powder, flax seed powder, whey protein powder, etc. However, these food supplements are expensive and, therefore, they are not that accessible to a number of people at the household level. Therefore having an indigenous knowledge system (IKS) and modifying the local food among the marginalized population for viable food and nutrition security is needed for attainable livelihoods and the viable progress of any nation. *Moringa oleifera* has been ascribed as cost effective and its use is considered a sustainable strategy to improve nutrient intake in vulnerable communities. Its benefits extend to immunizing the human body against some diseases.

Home supplementation of foods, including complementary foods, has been proposed as a viable intervention strategy, especially for improving the micronutrient intake in children under two years of age (De-Regil *et al.*, 2013). However, whole food supplementation could also be a viable measure for controlling micronutrient malnutrition (Dhakar *et al.*, 2011b).

Home supplementation is being viewed as an innovation aimed at improving diet quality of vulnerable groups such as young children and women within child bearing age group. This has been achieved through the use of Micronutrient Powders (MNPs) which are obtained in sachets containing dry powder with micronutrients which can be added to semi-solid or solid food prior to consumption. This practice is aimed at ensuring that both complementary foods and breast milk will meet the nutrient needs of young children (de Alimentos and UNICEF, 2011). However, *Moringa Oleifera* leaf powder could also be incorporated in food preparation as a supplement, since the aim is to enhance the nutritional value of the food.

South Africa is situated within a continent that is rated with a high prevalence of micronutrient malnutrition. Young children and women who can give birth to young ones appear at risk of a high vulnerability because of rapid population growth and inadequate dietary practices (De-Regil *et al.*, 2013, Vist *et al.*, 2011). Thus, the ability to be self-reliant and to fortify/supplement indigenous staple foods with nutrient-dense bioavailable food sources at home cannot be overemphasized, since home fortification is an avenue through which micronutrient supplement and food fortificants can be added to the food of consumers in the home. *Moringa Oleifera* is

considered cost-effective for animal and human food supplements. However, it is vital to note that the absorption of micronutrients can be strongly influenced by the combination of foods that are consumed in a given meal (Tontisirin *et al.*, 2002).

Therefore, regardless of choice or preference, the home fortification/supplementation of certain foods, such as beverages, drinks, and snacks with fruit and vegetables can be regarded as a delivery channel for a sustainable conveyance of micronutrients to all consumers.

2.5.8 Constraints of dietary diversification

Although the positive benefits of dietary diversification have been highlighted, dietary diversification suffers from difficulties in terms of people's unwillingness to change their dietary habits to the modified diet (Gibson and Hotz, 2001). In addition, there have been constraints in achieving dietary diversification, especially among the underprivileged. Some of these constraints include extreme poverty that hinders people from accessing or purchasing safe and nutritious food and promotes a lack of proper information, knowledge, and education about nutrition which perhaps leads to the inability to select and prepare nutritious foods which would consequently steer people away from an unhealthy dietary lifestyle.

2.5.9 Nutritional benefits of fermented food

Mahewu is a fermented drink, and the effects of fermentation of foods (*mahewu*) have been linked with increased digestibility of protein, improved nutritional and sensory quality of maize-based foods and also a reduction in the levels of toxic/carcinogenic mycotoxins (Chelule *et al.*, 2010b). According to Daglioglu (2002), fermentation of maize-based porridge also leads to a general enhancement of the drink shelf life, texture, taste and aroma, nutritional value and digestibility and it also significantly lowers the content of anti-nutrients of cereal products, and such porridge is high in fiber content which in turn will aid digestion (Daglioglu *et al.*, 2002). During the *mahewu* fermentation process, there is a significant increase in the total amount of soluble sugars, reducing and non-reducing sugar content, with a simultaneous decrease in the starch content (Khetarpaul and Chauhan, 1990). Lactic acid bacteria LAB play a vital role in food fermentations where they not only contribute to the development of the desired sensory properties in the final product but likewise to their microbiological safety.

During fermentation, certain micro-organisms produce vitamins at a higher rate, and this could be an additional reason for the increased interest in fermented foods. It has been found that fermented beverage could promote the functions of the human digestive system in a number of

positive ways. This contribution is called the probiotic effect. The Primary activity of the culture in the fermentations of *mahewu* beverage is to convert carbohydrates to the desired metabolites such as alcohol, acetic acid, lactic acid or CO₂ (Ziatica *et al.*, 2007). Furthermore, a study conducted in Zimbabwe reports that the frequent use of fermented foods such as *mahewu* have been helpful in alleviating diarrhea and malnutrition caused by an inadequate intake of food and unfavorable feeding patterns of young children (Gumede and Chelule, 2014).

Moreover, *mahewu* enhances the human diet by way of developing a wide diversity of unique flavors and textures in the food within the shortest possible time (Awobusuyi, 2015). These nutritional values that are derived from the fermentation process are, therefore, also applicable to the *mahewu* beverage, and it emphasizes its advantage as a valuable source of the required nutrition that is negatively affected by famine, and has the added advantage that it increases in quantity when water is added to it and it still retains its flavour (Ndulaka *et al.*, 2014). It is a cost effective product for regulating the immune system and gastrointestinal tract (Gaffa *et al.*, 2002). In addition, people derive satisfaction from the fermented taste of cereal beverages. Fermented food products forms part of many social, cultural and consumption patterns, especially regarding fermented beverages (Blandino *et al.*, 2003).

Since fermentation reduces spoilage of many fermented cereal products, it then offers added advantages to both sellers and consumers. Perhaps, this might be one of the leading reasons for the high demand of fermented cereal products, especially during particular seasons such as summer; it is used to entertain people in social and cultural events as well as during ceremonies, such as weddings. In addition, fermented foods have been known to provide some nutritional benefits which are associated with probiotics, a bacterium that feeds the colon (Parvez *et al.*, 2006). Furthermore, it proved scientifically that fermentation improves food preservation, and the removal of the anti-nutritional factor (Marshall and Mejia, 2011).

Cereal-based complementary foods are in high demand as the main source of nutrients for many infants in developing countries (Blandino *et al.*, 2003). However, if it is over-relied on as main meal without enhancing the nutritional value, compromising the maize-based food products alone, will present micronutrient (vitamins and minerals) deficiency health problems (von Grebmer *et al.*, 2014). Also, providing inadequate foods such as those that are maize-based without supplement might not provide safe diets for older infants and young children because of the deficiency in essential amino acids (Thompson and Amoroso, 2010). Research into the processing technologies of beverages using different substrates is still in its infancy stage,

therefore, it is important that the most sustainable supplements for enhancing their nutritional value be studied and used, which is the focus of the present study.

2.5.10 The negative effects of fermented foods

The fermentation of food causes the decomposition of the food, thus, certain waste products are produced by the bacteria which break down the food, generating the required stability, safety and the unique sensory property of the product. One of the by-products is alcohol (Ziatica et al, 2007). Although alcohol in fermented foods is usually present in small quantities, except when it is beer, but even the long-term effects of small amounts of alcohol have been noted to negatively affect the cells of the body. Heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd) and arsenic, including phytates and tannins are also present (Food Resources, 2006, Aka *et al.*, 2014). Notwithstanding, ammonia is another product of fermentation and it is even reported to be dangerous when used as a house-cleaning agent, hence, it would be advisable to not eat foods containing ammonia (Ziatica et al, 2007). Vinegar, in the form of *acetic acid*, resulting from food fermentation, is responsible for any sour or sharp taste (Ziatica et al, 2007). The sharp taste is an indicator to the body that the food should not be eaten as it is potentially harmful. Vinegar prevents the digestion of foods, hence a food loaded with vinegar and other similar by-products would seem to be indigestible (Food Resources, 2006). However, the sour taste is the unique taste that makes *mahewu* peculiar, desired and refreshing, especially in the summer months.

The fermentation of porridge that resulting to *mahewu* beverage is caused by *lactic acid bacteria*, which has lactic acid as a waste product, which is beneficial to human health. Positive benefits have been mentioned on fermented foods, however, the stiffness of the body causing discomfort in the wellbeing has been associated with lactic acid fermented foods (Ziatica et al, 2007). It is noteworthy that foods with the highest nutrition are those which are eaten in their fresh, natural and unprocessed state (Food Resources, 2006). As soon as a food is modified in any way, nutrient loss results. Fermentation undergoes a natural shelf life, thus, the longer a food is held in storage processes, the lower it becomes in its nutritional content (Food Resources, 2006).

2.6 The importance of fruits and vegetable consumption

Fruits and vegetables are chief sources of essential vitamins and minerals and can provide substantial food nutrients that are required in the daily diet of humans (Liu, 2003). Most of the nutrients of the foods that humans need for a healthy and active life are plant-based. Thus, fruits and vegetables and especially the dark green and orange vegetables provide most humans with essential nutrients (Lewu and Mavengahama, 2011). Generally, the dark green leafy vegetables such as *Moringa Oleifera* are considered rich sources of nutrients, which include phytochemicals and antioxidants that are able to prevent and combat deficiency diseases such as cancers, cardiovascular problems, and diabetes and to provide food security. In spite of the nutritional benefits embedded in fruits and vegetables, their consumption is still generally low in sub-Saharan Africa and in South Africa (Fuglie and Sreeja, 2001, Hillocks, 2011).

2.7 Underutilization of vegetables

Generally, the human dietary lifestyle can be shaped within the ecological setting, in that an individual lives in the settings that include environmental, social and cultural factors as well as personal preferences (Nicus, 2016). According to the literature, the low consumption of vegetables is a result of low income, poor nutrition knowledge, low level of education, including lack the knowledge of nutrition, living in an underprivileged population, and low socio-economic status (Nicus, 2016). Furthermore, a lack of knowledge and/or the wrong perceptions, gender discrepancies, personal preferences or cultural differences are all associated with a low consumption of vegetables and fruits. Strangely, it is also generally perceived that vegetables are expensive (Valmórbida and Vitolo, 2014). Therefore, creating greater awareness with emphasis on the nutritional benefits of vegetables and fruits and their constant incorporation into daily foods and diets will serve as a means to encourage consumption among consumers (Van Jaarsveld *et al.*, 2014). The WHO and the joint report of a Global Strategy on diet, Physical Activity and Health, recommend a minimum daily intake of 400 g of fruits and vegetables (Waxman, 2004, Smith and Eyzaguirre, 2007). Thus, nutritionists must seek to help consumers realize that for every individual older than three years of age, the current recommendations for fruit and vegetable intakes are greater than the familiar five servings per day (Nicus, 2016).

The reason is that there are nutrients that have been viewed as essential food components which cannot be made by the body, yet are needed for optimum health (Liu, 2003). For example,

vitamin C must either be consumed from synthetic supplements or else it must be provided in an adequate amount from the individual diet(Uusiku *et al.*, 2010). The reason is that synthesis requires a definite factor that may not be found in certain conditions or, in other cases, it exists in inadequate quantities (for example, some amino acids, fatty acids, and vitamins(Smith and Eyzaguirre, 2007). Phytochemicals in plant foods have been associated with positive effects on human health, including coronary heart diseases, diabetes, high blood pressure, cataracts, degenerative diseases, and obesity (Madukwe *et al.*, 2013).

Diseases of various kind can be prevent and wellbeing promoted when fruits and vegetables forms part of a regular diet of humans(Uusiku *et al.*, 2010). Over the years, scientific evidence linking fruits and vegetables with benefits to good health has continued to expand(Nicus, 2016). However, it is reported globally that a high percentage of women in the productive age group appear to not meet the recommended daily consumption of several micronutrient and key nutrients; these include calcium, folic acid, and iron(Uusiku *et al.*, 2010). A survey shows that only 4% of women aged 19-24 years consumed their five-a-day target with respect to fruits and vegetables(Torrens, 2016). In South Africa, however, a study reports that the consumption of fruit and vegetable intake per capita in children between the ages of 1 and 9 years, is considerably low as it reflects low fruit and vegetable intake, which accounted for 3.2% of total deaths and 1.1% of the 16.2 million ascribed to the disability-adjusted life years in DALY(Tsegay et al, 2014). South African previous study among the adult population as far back as 2003 revealed that 72.2% of men and 66.7% of women (Phaswana-Mafuya and Peltzer, 2015).

Vegetables are inexpensive to grow and they are sustainable in a cost-effective way for combating micronutrient challenges(Van Rensburg *et al.*, 2004). Therefore, vegetables form an important part of the human diet and are regarded as a major bioavailable active source of vitamins and minerals which can fight micronutrient deficiency and provide dietary fiber, antioxidants, and cholesterol-lowering compounds(Uusiku *et al.*, 2010). These compounds serve to protect the heart against heart diseases, slow the progression of age-related muscle degeneration, and boost the immune system of young children. Moreover, vegetables are good sources of oil, carbohydrates, minerals and vitamins to humans depending on the vegetable consumed(Van Jaarsveld *et al.*, 2014). Vegetable fats and oils also lower blood lipids, thereby reducing the occurrence of diseases associated with the damage to the coronary artery(Van

Jaarsveld *et al.*, 2014). Therefore incorporating vegetables such as *Moringa Oleifera* in a less nutrient-dense maize-based diet like *mahewu* could constitute an essential component of the human diet by contributing essential amino acids, vitamins, iron, calcium and other essential nutrients.

Moringa, as a nutrient-rich vegetable, could be eaten fresh and processed locally, as well as added to food for enhanced food and nutrition security that would contribute towards reducing micronutrient deficiencies (Yang and Keding, 2009). Thus, this review establishes that the inclusion of this nutritious vegetable food plant through either fresh leaves or dried powder in local dishes appears to be promising, especially in enhancing staple-based food products and as well tackling most of the preventable malnutrition, especially micronutrient deficiency health challenges, with more reference to the less-privileged population. Therefore, sub-Saharan African countries including South Africa can explore the nutritional and the therapeutic effects of this *moringa oleifera*, thereby making a great difference in the food and nutritional status of many communities with less-privileged people who are at risk of malnutrition and especially deficiency and hidden hunger challenges.

CHAPTER THREE:

Utilization of mahewu, a fermented maize meal-based beverage, in Ntambanana (KwaZulu-Natal, South Africa) and its potential for fortification with *Moringa oleifera*

Abstract

Mahewu is a fermented popular non-alcoholic beverage in sub-Saharan Africa, the Arabian Gulf and it is a traditional beverage in southern Africa. Almost all household members from infants consume it, to the elderly. A maize meal-based porridge beverage is known to be lacking in essential amino acids and micronutrients, especially if it is made from conventional maize. Hidden hunger is steadily persisting in being a challenge, due to common reliance on monotonous diets. One eats food (quantity) but is the food filled with the necessary nutrients (quality) that required by the body in order to be leading a healthy and an active life. In Ntambanana village (KwaZulu-Natal, South Africa), Moringa oleifera (Moringa) is grown; however, its utilization as food by the community has not been exploited. Moringa is an edible and easily cultivated plant that is used in about 80 countries. It possesses vital minerals such as vitamins A, the B vitamins: (1, 2, 3, 6, and 7), C, D, E and K, calcium, potassium copper, iron, magnesium, manganese and zinc. It also has more than 40 natural anti-oxidants. Household fortification through addition of foods with high micronutrient density to starch-based beverages could improve their micronutrient value. This is quite important if the households still rely on conventional maize or hop in-between purchasing commercial fortified maize when their local grown maize is off season, because these households indirectly expose themselves to hidden hunger. The conventional maize is lacking essential amino acid, vitamins and minerals, except when indigenous processing methods are applied, which seem to be disappearing from generation to generation. This study assessed the utilization of mahewu in Ntambanana and perceptions of Moringa oleifera as a food. Forty-six randomly-selected representative households were interviewed in focus group discussions. Findings of the study showed that 95.7% of respondents drink mahewu. Its consumption was reported to be at its highest in summer (43.5%) and lowest in autumn (2.2%). The chi-square test revealed a significant difference ($p < 0.05$) between the frequency in consumption and the reason for its consumption. About 84% of respondents add sugar when preparing the beverage, 2.2% add fruits, while 13.3% add nothing to their mahewu drink. The community mainly relied on locally-produced (conventional) maize for acquiring maize meal used for preparing mahewu and only bought fortified maize after their harvesting period was over. It was surprising to find that although Moringa is planted in the community, an overwhelming 78.3% of the locals did not know much about it as a food item. Close to half (41.3%) of the respondents were not sure whether Moringa is herb or not, 19.6% thought it was a herb, while 39.1% believed it was not a herb. Thirteen percent of the respondents thought it could be added to food as a supplement and/or seasoning and 45.7% of the respondents lacked any knowledge about the possible uses of Moringa as a herb and/or food. Nevertheless, 47.8% declared willingness to embrace Moringa if encouraged to take it for health and nutritional benefits, 21.6% were uncertain, while 26.1% showed less interest. To enhance the nutritional value of mahewu, Moringa could be used in this beverage. However, there is a need to create awareness as Moringa is not well known.

3.1 Introduction

Mahewu is a southern African fermented non-alcoholic beverage (Awobusuyi et al., 2015b). This beverage is very popular in Kwazulu-Natal, South Africa, hence, in South Africa it is locally known as ‘amahewu’ (Zulu), ‘emahewu’ (Swazi), ‘metogo’ (Pedi), ‘machleu’ (Sotho), ‘maphulo’ (Venda) and ‘amarehhu’ (Xhosa) (Idowu et al, 2016), however, the most common term is “mahewu”. Although mahewu is available commercially, it is also produced at the household level. The beverage is processed from white maize using 8-10% of maize meal as

the major solid substrate in an aqueous suspension. Traditionally, spontaneous fermentation involves Lactic acid bacteria (LAB) and yeast can also be used. It can also be fermented using a culture as a starter, such as malted wheat flour and millet (Salvador, 2015). Fermented foods such as *mahewu* are valuable in the African diet and they account for the bulk of the caloric consumption in African countries. *Mahewu* is consumed by individuals of all age groups: adults, preschool children and school-going children, and it is even used as weaning foods for infants among poor-income rural communities. However, white maize is deficient in some essential vitamins and minerals (Awobusuyi *et al.*, 2015a). Therefore, relying on *mahewu* as a staple can predispose individuals to the challenges of malnutrition. Studies have established that malnutrition, especially micronutrient malnutrition (also known as hidden hunger), is a major public health problem (Ruel-Bergeron *et al.*, 2015, Fayemi *et al.*, 2016), which is commonly evident among populations of low-income countries. A study conducted in Ndunakazi, KwaZulu-Natal, showed that 44% of pre-school children and 52% of primary school children were vitamin A deficient (Lewu and Mavengahama, 2011). Another study showed that boys and girls of age (0-3 years of age) had the highest prevalence of stunting (26.9% and 25.9%), with the lowest prevalence recorded among the 7-9 years age group (10% and 8.7%, respectively) (HSRC, 2013).

Incorporating *Moringa* in staples (*mahewu*) has the potential for alleviating all forms of malnutrition, especially micronutrients deficiencies. Sub-Saharan African countries are challenged with malnutrition problems that are mostly prevalent among the less-privileged rural population and the disadvantaged population in urban informal settings with the most widespread being factors such as iron, Vitamin A, iodine zinc, and now the B vitamins (Muthayya *et al.*, 2013a, Ruel-Bergeron *et al.*, 2015). The literature reports that in South Africa, the KwaZulu-Natal province is among those provinces that are challenged with nutrition-related health problems (malnutrition, especially micronutrient deficiency such as iron and Vitamin A deficiency (VAD) (Tsegay *et al.*, 2014, Govender *et al.*, 2016). *Moringa* has been explored for its nutritional benefits for attempting nutrient-related challenges. The present study assesses how *mahewu* is utilized in Ntambanana, a rural community in KwaZulu-Natal (South Africa), and aims to determine the perceptions about the use of *Moringa* to enhance foods.

3.2 Materials and methods

3.2.1 Description of the study area

The study was conducted at Buchanan in Ntambanana Figure 3.1, Ntambanana is Municipality under uThungulu district, and it covers a vast area of land (1,083 km²). Based on 2007 community survey, the population of Ntambanana is reported to be 94,194. About (85%) of the land in the municipal area of jurisdiction belongs to Ingonyama trust and 15% of the land is privately owned by commercial farmers. (IDP, 2013/2014). The close area around Heat on Ville is predominantly private, owned and utilized by subsistence farmers who are growing vegetables, nuts and maize. The rural population is engaged in farming, and the farmers practice cattle farming and other agricultural activities (IDP, 2013/2014). The implementation of the property rates is a base in revenue are collected as the municipality is able to collect rates from farmers since the 2007 /2008 financial year. Ntambanana municipal is challenged with high poverty as result of unemployment, its dependency on impartial share of land and other government grants, pension and social grants(IDP, 2015). *Moringa oleifera* which is *multipurpose and a promising plant* is a government project that currently is on-going in the area however, it is being underutilized as food.



Figure 3. 1: Map of Ntambanana Municipality (Jozini Area map, 2017)

3.2.2 Sampling procedure

In this study, a combination of a quantitative and qualitative approach (an integrated approach) where a survey and four focus group discussions were carried out, respectively, to gather data.

The survey was conducted with 46 *mahewu* consumers, whereby a convenient sampling technique was used. A questionnaire was administered by going from house to house to gather data on the utilization of *mahewu* in order to understand who drinks it, how it is prepared, the season for consumption and the frequency of consumption. Furthermore, perceptions of *Moringa oleifera* as a proposed food material for enhancing starch-based food products were investigated. Table 1 presents the demographic characteristics of the study participants. The respondents were classified according to gender, age, marital status, household headship, level of education, employment status, source of income and average money in the household. Eighty-three percent (83%) of the participants were females and 17.4% were male. Four percent of the participants were below 20 years of age. Thirty-two percent (32%) were pensioners and 26.1% collected social grants regularly.

Table 3. 1: The demographic characteristics of the study participants

Characteristics	Categories	Frequency (%)
Age	Male	17
	Female	82
	Below 20 years	4
	20-40 years	33
	41-50 years	22
Marital Status	Above 50 years	41
	Single	53
	Married	38
	Widowed	9
Household headship	Yes	35
	No	65
Level of education	No formal education	28
	Primary education	28
	Secondary education	39
	Tertiary education	4
Employment	Full time	7
	Part time	29
Status	Unemployed	65
	Wages	20
	Salary	20
	Pension	33
	Social Grant	26
	Others	2
	Below R800	20
	R801-1500	52
	R1501-3500	22
	Above R3500	7

The literature suggests that households depending on social grants are mostly vulnerable to food and nutrition insecurity because of limited resources to purchase nutritious food for the household and to meet other needs (Patel, 2012). Therefore, the limitation in financial resources of these households could compromise their food and nutrition security, as observed from the average money in the household. The data show that the lowest income for these households is R800 and the highest is R3, 500 per month.

After the survey, a focus group discussion, where a collective activity of a social events and interaction, was conducted in the study area as a tool to gain more insight into the respondents' attitudes, feelings, beliefs, and experiences about the topic of this study. This was suitable for

this study because people's reactions, opinions and understanding could be better obtained before making valued conclusions in a way that would not non-feasible when using other methods. Information was gathered by talking to a group of people who were available at the venue. The researcher (myself) and the research assistants had an informed interactive discussion and then probing took place. For a participant who consumes *mahewu*, questions such as -why do you like *mahewu*? - was probed and such a platform provided an avenue for the participant to feel free and to communicate their opinion and to express their feelings about why they like *mahewu*. Also, questions on *Moringa* were probed whereby a participant would express their knowledge of and what they feel about the *Moringa oleifera*. During the focus group discussions, some people would express themselves to the effect that *Moringa* arouses their instinct of sexuality, and to some others *Moringa* is perceived to be purely medicinal rather than a food plant. Some perceived *Moringa* plant as an alien plant thus they never bothered to find out what it is meant for, let alone using it as a food. For some, *Moringa* could be used as biofuels, in that the plant grows into tall trees that can be utilized as such. Despite government effort for introducing *Moringa oleifera* as a project that can contribute to alleviating human suffering and tackling nutrient deficiency challenges, *moringa* is yet to be actualized as a food plant, thus *Moringa* is underutilized by the rural community as a food. Because the focus group discussion was interactive the responses which participants could not have been able to write down, were noted during the discussion by myself or the research assistants.

3.3 Results and discussion

3.3.1 Utilization of *mahewu*

As shown in Table 3.2, a total of 95.7% of the respondents in Ntambanana rural households drink *mahewu*. The respondents considered *mahewu* to be wholesome, filling and suitable as a weaning foods for infants from four months of age.

Table 3. 2: The percentage of households who consume *mahewu* in Ntambanana

Response	Frequency	Percentage
Yes	44	95.7
No	2	4.3
Total	46	100.0

In Table 3.3, 43.5 percent of the households consume *mahewu* in summer, 37.0 consume it throughout the year, while 2.2% consume it in autumn. Considering these statistics, *Mahewu* is largely regarded as a summer beverage, because it was described as a light drink which is usually desired during the summer season. This shows the importance of *mahewu* as not only a refreshing beverage but also as a beverage which could serve a dual purpose of being both refreshing and filling. *Mahewu* in other countries such as Nigeria, west Africa, has its peak consumed in the dry and hot season (Gaffa *et al.*, 2002).

Table 3. 3: Seasons in which mahewu is mostly consumed

Seasons	Frequency	Percentage
Autumn	1	2.2
Winter	3	6.5
Summer	20	43.5
Any season	17	37.0
No response	5	10.9
Total	46	100

3.3.2 Traditional preparation of *mahewu*

The most prevalent participant response was that *mahewu* is prepared based on an estimation of the ingredients, thus, there was no standard or specific recipe for *mahewu*. However, the general information gathered concerning the preparation of *mahewu* in the focus group centers are as follows:

Water estimated based on the quantity of the porridge desired, it is boiled in an earthen pot, a portion of the meal maize is poured into a bowl, cold water is added and it is mixed very well into a paste, whereby it is then poured into the boiling water and stirred continuously and very well to avoid lumps. It is stand to cook for about 20 minutes, until a smooth and creamy porridge is obtained. Cold water is added to the cooked porridge, and it is allowed to cool to a lukewarm(tepid) condition, and then sugar is added and it is left in a warm and dark place, for instance in a cupboard overnight, to undergo natural fermentation. Finally, the *mahewu* beverage is served cold

The common opinions of Ntambanana rural household regarding utilization of *mahewu* were that *mahewu* is an indigenous beverage and everyone in the house, regardless of their age, drinks

mahewu - from infants to the elderly. Those belonging to low income households, it was the main meal of the day. Young children also drink *mahewu* as a meal (Awobusuyi *et al.*, 2015b). The participants' opinions about the consumption of *mahewu* were due to it being a very nutritious, appetizing and refreshing drink after hard work on hot days. Manual laborers can easily access a common drink as it fuels their energy for work. It was also noted that it can satisfy hunger, meaning that it can be consumed as the main meal of the day. Besides the refreshing and appetizing nature of *mahewu* drink in the rural household, the findings of this research indicate that there is a limited knowledge among the participants with respect to the nutrition of the maize-based food products, but the participants generally responded that *mahewu* is very nutritious. The literature notes that although maize constitutes the bulk of the diet of humans and animals, white maize is inadequate and especially regards the essential nutrients (protein and micronutrients). Thus, not all maize-based foods are adequately nutritious but rather they are deficient/inadequate in most of the essential micronutrients.

3.3.3 Frequency of consumption of *mahewu*

Table 3.4, shows the frequency and percentage of consumption of *mahewu* in the rural households of Ntambanana. A total of 35.78% households consume the beverage at a rate of more than three times a day. This implies that some people in rural households appreciate the beverage as a refreshing and as a wholesome and filling food. Since the percentage frequency is high, the individuals who mostly rely on *mahewu* without other sources of essential nutrient such as fruits and vegetables are likely to be predispose to food and nutrition in security.

Table 3. 4: Frequency of *mahewu* consumption in Ntambanana households

Rate Consumption of <i>mahewu</i>	Frequency	Percent
More than 3 times per day	16	35.78
Once a week	9	19.57
Once a month	7	15.22
Occasionally	11	23.91
No response	3	6.52
Total	46	100

Table 3. 5: Food complements of mahewu (whatever is added to mahewu before consumption)

	Frequency	Percent
Fruit	1	2
Sugar	39	85
Nothing	6	13
Total	46	100

3.3.4 Food complements of *Mahewu*

In Table 3.5, 85% of respondents' added sugar only, 2% add fruits, while 13.3% add nothing to their *Mahewu*. Therefore, since quite a number of the respondents added only sugar to the *Mahewu* beverage, and it is aforementioned that over-reliance on such a beverage as a filling food without enriching it with either fruit or vegetables can make the population food and nutrition insecure. This is so because a long-term reliance on such a dietary life style is able to expose the most vulnerable group to the challenge of micronutrient deficiency, especially if the *Mahewu* is produced from the unfortified maize that is nutritiously inadequate and deficient in essential micronutrients. Thus, the less privileged rural households can be predisposed to micronutrient deficiencies, and a conscious effort of availing essential nutrient in the diet that is inadequate in essential nutrients plays a key role in providing nutritious food for human consumption (Holzapfel and Taljaard, 2004, Awobusuyi *et al.*, 2015b). The participants who were adding only sugar to their *mahewu* showed that they lack exposure on how *mahewu* can be nutritionally improved. The nutrition about their diet and food diversification might be lacking in such households, especially if they frequently use it as a filling and weaning food, hence their food and nutrition security is unascertained thereby becoming vulnerable to micronutrient deficiencies.

3.3.5 Perceptions of *Moringa*

In Table 3.6, the study reveals that most of the respondents (39%) were unfamiliar with *Moringa*, while only 20% were familiar with *Moringa*. Although *Moringa* is grown in the community, the findings show that the majority of the respondents lack awareness on *Moringa oleifera*. This is so because most of the participants were not sure of what *Moringa* is. Thus, the Chi-square test shows that there is a statistically significant difference in data for each of the responses to the structured questions numbered 8-11, all of which focus on awareness and perception of *Moringa*, in that, the data consistently show a low level of awareness. This implies that a large percentage of Ntambanana have no idea of what *Moringa* is. Furthermore, in Table 3.7, over a third, 36 of the respondents could not answer whether *Moringa* is herb or not. A similar observation is made for the question which asks whether *Moringa* can be added to food, as well as the question which asks if the respondents have ever used *Moringa*. The responses clearly indicate that only a limited number of the Ntambanana rural households are aware of and consume *Moringa*.

Table 3. 6: Perception of *Moringa* (Are you familiar with *Moringa*?)

Response	Frequency	Percentage
Yes	9	20
No	18	39
No response	19	41
Total	46	100

Table 3. 7: Perception of *Moringa* (Is *Moringa* a herb or a food?)

Response	Frequency	Percentage
Yes (herb)	10	22
No (food)	36	78
Total	46	100

3.3.6 Perception of *Moringa oleifera*

In Table 3.7, the response to whether *Moringa* is a herb or a food show some level of consistency with the fact that most rural households are not familiar with *Moringa*, as 22% think it is a food, while 36% think it is not a food but is herb; when indeed it is a food and it can be added to food. Also, in Table 3.6, 41% are unfamiliar with *Moringa Oleifera* as the participants could not answer the question of whether *Moringa* could be added to food. The bottom line is that *Moringa* is not well known, either as a food or as a herb. However, the literature reports that in other countries in Africa, particularly the West African countries, there is an indication that

Moringa is usually perceived of and is used as a food, and more awareness is being gained due to its high nutritional and economic value (Monera and Maponga, 2012, Farinola *et al.*, 2014). But, this is in contrast to the Ntambanana rural households in South Africa. Hence, it clearly shows the general low level of awareness of *Moringa* as a food. With all the provisions, *Moringa* stands to offer something nutritional and economic (Oyekale, 2012), but there is a limited awareness of *Moringa* as a food in the rural community of Ntambanana, KZN, South Africa.

Table 3. 8: Perception of Moringa (Can Moringa be added to food?)

Response	Frequency	Percentage
Yes	6	13
No	21	46
No response	19	41
Total	46	100

Table 3. 9: Perception of Moringa (Have you ever used Moringa?)

Response	Frequency	Percentage
Yes	4	9
No	24	52
No response	18	39
Total	46	100

Although *Moringa* is grown in the region under study, and it has the potential to alleviate human suffering via nutrient health-related challenges (malnutrition), the information in Figure 8 is clear that the rural household are not aware of the *Moringa*, therefore, affecting their attitudes to *Moringa oleifera*. The most valued drink identified in Ntambanana is a concentrate drinks. However, some prefer *mahewu* because it is an indigenous drink which is easy to prepare at home using the locally available maize and utensils. Notwithstanding, it is consumed by everyone in the household because it has a unique taste and therefore it is appetizing. Also, for some people, due to a lack of finances it is the available meal of the day for everyone in the household, especially as it is a common meal for young children. Thus, it was identified in this study that the food security of some household particularly infant who are weaned from breast milk majors on this drink as their vitamins and energy is being derived from *mahewu* for the day (Awobusuyi *et al.*, 2015b).

3.3.7 Potential in using *Moringa* to fortify *mahewu* beverage

Although worldwide *Moringa oleifera* is gaining recognition as a food-based approach for tackling nutrient related challenges, awareness about *Moringa* as a food plant in Ntambanana, KZN, is still very low, yet *Moringa* has the potential to tackle malnutrition (hidden hunger), especially for those who cannot access sufficient animal protein, fruit and vegetables which is a problem. The majority of the respondents lacked knowledge of the *moringa oleifera* plant. Few participants who have heard of it know it as herb. Others perceived *moringa oleifera* is a medicine, which should be taken only when there is illness. While some attest that they have seen *moringa oleifera* plant at Luwamba, but they never bothered to find out what is the use of it. In addition, some participants noted that *Moringa* is for biofuel purposes. Findings reveals that majority of households are not familiar with *Moringa oleifera* so to some it is not considered as food. Limited number of participants who used *Moringa* as food were above 50 years of age, this might should something about the better awareness of *Moringa oleifera* as food among the older generation compared to the younger generation.

3.4 Conclusion

The findings of this study indicate that the utilization of *Mahewu* in rural households of Ntambanana was very high. Concerning *Moringa*, the majority of households are not familiar with *Moringa oleifera* or they omit its usage as a food and, consequently, a limited number of participants used *Moringa* as food. It was also discovered that the only respondents that used *Moringa* as a food were above 50 years of age, and this may suggest something about the better awareness among the older generation. However, it is noteworthy that a large proportion of respondents noted that they would gladly embrace *Moringa oleifera* if they were encouraged to do so, and they accepted to think about how to take it functional as a food and for health benefits. Likewise, with the focus group discussions, the respondents' opinions regarding consuming *mahewu* note that it is a nutritious and refreshing beverage on a hot day. It was identified that the respondents' reasons regarding liking *mahewu* relate to being their ingenious beverage and a food that is easy to prepare - which classifies it as readily available. These preferences were the major concern of those participants rather than the nutrient composition of the *mahewu*. This clearly indicates a lack, or limited knowledge, of the nutritional deficiency of a homemade *Mahewu* beverage, especially if made from unfortified maize. Only a few of the respondents were familiar with *Moringa* as a food. Therefore, there is a need for creating an awareness on the utilization of *Moringa* as a food and as a food supplement for improving food and for improving nutrition security in the Ntambanana community.

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CHAPTER FOUR

Processing of *mahewu*, a non-alcoholic maize meal-based beverage, in Ntambanana, KwaZulu-Natal, South Africa

Abstract

In southern Africa, maize is the basic ingredient for fermented maize meal-based beverage Mahewu. Most rural communities can produce Mahewu at the household level and it is the main source of dietary energy nutrients. Unfortunately, the indigenous-based recipes and practices are not well documented. The present study aimed to document the practices of making Mahewu in a Zulu-based household, in Ntambanana rural community, KwaZulu-Natal which is a province of South Africa. A phenomenological research approach was adopted in this study to attain and document the perspective and practices of making the Mahewu beverage. The key interviews were complemented by four focus group discussions, within the range of 10-12 participants who were consumers of the local non-alcoholic beverage. The findings show that Mahewu soft fermented porridge known as 'umdokwe' is consumed by all age groups from four months of age to the elderly. Sweet potatoes were used as fermentation process enhancers and household fortification agent to enrich the drink with vitamin content. The drink has several health, food and nutrition security benefits for all age household members. However, due to diminishing indigenous knowledge and the inadequate transmission of such knowledge between generations, this health benefitting non-alcoholic drink could soon only be available and accessible commercially. Retention of the techniques of the old days with respect to modifying foods at the household level should become a key role in encouraging the rural community to appreciate their nutritional drinks. Documentation of recipes and practices of making this beverage have to be recorded and shared with generations to come. Moreover, it is recommended that campaigns promoting indigenous foods and beverages should form part of health, social development/welfare, food and nutrition interventions and they should be promoted.

Key words: *fermentation, indigenous beverage, practices, fermentation process, enhancers*

4.1 Introduction

Maize constitute the main ingredient in the diet of most rural dwellers and among disadvantaged settings in sub-Saharan African countries. Cereals such as maize make up more than 60% of the world's food harvest (Todorov and Holzapfel, 2015). Maize contains a high amount of starch (65 to 75% carbohydrate weight), and low levels or low availability of proteins (6 to 12%) and fat (1 to 5%), with some traces of minerals and vitamins (Sarwar *et al.*, 2013). Hence, some researchers report maize as being devoid of nutritional value, especially when consumed without other adequate complementary protein, mineral and vitamins food sources. Nevertheless, researchers argue that some other indigenous processing methods or value adding processes, have some health benefits as they managed to avail of some of the nutrients (Blandino *et al.*, 2003, Rhee *et al.*, 2011).

Fermentation improves the bioavailability of vitamins and minerals, thus, it is known to improve human nutrition by contributing to food security of *mahewu* consumers therefore reducing the vulnerability of rural and urban food-insecure households, by improving livelihoods in the nation (Salvador, 2015). According to Chelule *et al.* (2010), the fermentation of soft porridge as *mahewu* is an old technology for handling food for the purpose of making it readily available, with a better keeping quality and satiating sensory attributes (Chelule *et al.*, 2010a). *Mahewu*, especially the indigenously made beverage which contains dietary fibers, including crude, soluble, and insoluble fibers which maintain a healthy bowel, lower cholesterol levels, and help control blood sugar levels (Şanlıer *et al.*, 2017).

Fermented foods such as *mahewu* are identified among the functional foods providing basic nutrition as well as health benefits (Şanlıer *et al.*, 2017). *Mahewu* is produced through lactic acid bacteria (LAB) (Idowu *et al.*, 2016). It has been extensively established that food fermentation depends on actively growing lactic acid bacteria which might be added as starter cultures or might be grown naturally in the food matrix. LAB, a group of gram-positive bacteria, unite by a constellation of morphological, metabolic, and physiological characteristics that are major constituents of the microbial ecology or probiotic starter cultures used in making fermented foods. LAB produces proton-motive force, mainly by means of a membrane located H^+ -ATPase at the expense of ATP. The proton-motive force drives the uphill transport of metabolites and ions into the cell (Akabanda *et al.*, 2014, Şanlıer *et al.*, 2017). It could therefore be stated that maize is a substrate for fermentation, which provides a medium for the bacteria to biochemically act on food with the end product of providing a desired *mahewu*, which is considered to be among the functional foods. Functional foods are those whole, fortified, supplemented, enriched or enhanced foods that provide health benefits beyond the provision of essential nutrients (e.g. vitamins and minerals); however, this is obtainable when consumed at adequate levels as part of a dietary lifestyle. Functional foods are important for providing the body with the required nutrients, such as vitamins, fats, proteins, and carbohydrates and also medicinal benefits that are necessary for healthy survival (Sangha, 2014). They are also reported to normalize intestinal flora, prevent gut infestation by bacteria and colon cancer, and treat diarrhea in both children and adults (Granato *et al.*, 2010, Lau *et al.*, 2012).

Unfortunately, Myeni (2015) reports that the indigenous knowledge of food and or beverage processing methods is slowly disappearing due to inadequate generational sharing (Myeni, 2015). On the contrary, the value of consuming commercially-made products which might not

offer the same nutritional value, social value and taste attributes is increasing (Myeni, 2015). This study explores the processing, consumption and documentation of *mahewu*, a non-alcoholic naturally fermented maize-based beverage in KwaZulu-Natal.

4.2 Description of the study area

Ntambanana Municipality is one of the six local municipalities under uThungulu District in KwaZulu-Natal. It is located in the central part of uThungulu District Municipality. It is approximately 160 km north of Durban and can be accessed through the R34 highway from Empangeni. The Municipality is surrounded by meandering valleys which accommodate numerous rivers flowing either towards the Umfolozi River in the North or the UMhlathuze River to the South. Based on the 2007 community survey, the Municipality covers an area of 1,083 km² and has a population of 94,194 people. According to IDP 2013/2014, the sex distribution of the Ntambanana population is reported to be 46% for females and 54% for males. This means that the male population as at 2013/2014 was higher than the female population. Ntambanana Municipality is rated as the poorest municipality because of its dependency on impartial share and other government grants, and the community-practiced subsistent farming. The farmers rely mostly on agriculture; they grow vegetables, nuts and maize. They feed on their local maize and alternate it with the commercial maize during the planting period. Myeni (2015) notes that the rural population also practices cattle farming and other agricultural activities. The maize is used to prepare several maize-based food products that are consumed indigenously as main meals, snacks and beverages (*Mahewu*).



Figure 4. 1: Map of selected study location Ntambanana (Jozini Area map, 2017)

4.3 Materials and methods

A qualitative research method was adopted in order to further explore and document the practices of making *Mahewu*. Key informant interviews using a phenomenological research were adopted. A phenomenological approach is a method of gathering data through inductive, qualitative methods including interviews, discussions and participant observations, and representing such data from the perspective of the research participant (Lester, 1999, Waters, 2017). During the phenomenological studies, four experts of *mahewu* drink making from different localities (2 local districts) of North Coast KwaZulu Natal were consulted and interviewed. In order to authenticate the information on the processes of making *mahewu*, two areas were selected to verify the information from the local communities within this part of the province. Through the help of a research assistant, the interview was recorded with an electronic recorder and which was later translated into the English language by a competent Zulu speaker who could speak English well enough for the task. An ethnographic approach was adopted whereby observations, interviews, and storytelling were followed in the study area. In addition, the researcher observed how *mahewu* was cooked in the rural community.

4.4 Data Analysis

The information gathered from the key informant interviews is detailed through descriptive narrative analysis. The historical-based method of making of *Mahewu* beverage was the topic of the research. The recorded information from interviews and focus group discussions was analyzed by descriptive content linking, themes and concepts.

4.5 Ethical Clearance

Permission was obtained from the department of agriculture under the Luwamba Center in Ntambanana as well as authorized permission with ethical clearance number: HSS/0559/01016 was granted by the University of KwaZulu-Natal Humanities, and Social Science Research Ethics Committee before the commencement of the study

Documentation of how the local maize-based beverage is processed and the other practices relating to its making is reported.

4.6 Results and discussion

4.6.1 Description of the non-alcoholic beverage

In the study area, the beverage is described as a soft fermented porridge, called umdokwe, which is regarded as a thirst quenching, hunger filling and convenient drink. It is usually a creamy-white fermented drink when is made from white maize, but if it is made from other maize varieties such as provitamin A biofortified maize it could be yellowish in color while if it is made from sorghum it would be a brownish color because of the inherent brown color. Both creamy white colored and brownish colored *Mahewu amanyama* (Black *Mahewu*) were considered to be popular, but white maize *mahewu* was the most popular across all the age groups.

4.6.2 Traditional processing of *Mahewu* beverage from own-grown maize.

According to the key informants, the processing begins by drying the harvested maize to preserve it. When a meal or a beverage is to be made, the dried maize kernels would be taken-off its cob. The maize kernels would be ground up on a flat stone and crushed using a more rectangular to oval and easy to handle stone in order to crush the maize kernels to make mealie-meal. The smaller stone would crush the maize and with more rigorous hard pressing movements while the grinder is kneeling down, the kernels would be crushed. This process would give a rougher maize meal, therefore, via a sorting process of taking off the maize outer coat as it is indigestible. Then, more grinding takes place until the maize meal looks more refined.

The grinding of maize formed part of the house chores of the women and female children. It is one of the skills that the older women would transfer to their granddaughters. In the traditional systems, the relationship between people involves the knowledge and the technologies being valued. Unfortunately, technology advancement is displacing some of the valued benefits although it could be argued that it brings forth greater convenience. To my knowledge, key informants attest that ‘Nowadays, such technology is outdated and the households make use of other technologies such as the minced meat grinder or if they have money they will send their maize to a local miller for milling.’

In this research, I observed that there were food retail stores that were selling fortified maize meal in this community, and as the people still relied on their local maize varieties, they were seasonal commercial (fortified) maize purchasers. Although the fortified maize meal offers

more nutritional value that was added to it and it relieves the women from strenuous household chores, there is another fundamental component of tradition that is being lost, that is, the sharing and transference of traditional knowledge between generations. Furthermore, there are commercial *Mahewu* beverages that are widely available in local markets, yet the consumers indicated their preference for the locally-made beverage that is made from their own grown maize or from the commercially-purchased maize meal that they acquired from the retail stores. It was also noted that the commercially-made *Mahewu* had an unpleasant after-taste unlike the traditional product. The locally-made *Mahewu* and especially from the own-grown maize, had a distinct refreshing sour taste which was more appreciated. There is an opportunity to retain the household making and consumption of *Mahewu* as sensory attributes such as taste tend to influence the utilization of food products.

4.6.3 The preparation and fermentation process of *Mahewu* in this study

According to the informants, traditionally *Mahewu* recipe was not quantified as measurements were not a priority to them. Generally recipe, quantities and time for preparation were estimated. Observations (looking at the texture of the porridge while it is cooking, its smell (a certain aroma indicates its rawness) and the mouth feel (using a wooden spoon) one would feel the texture and be able to detect whether the porridge was well cooked or not.

4.6.4 *Mahewu* preparation

Maize meal, 200g

Water 1900 ml

Sugar

(Starter is optional)

Preparation steps:

The first step is, boil the water quantity of about 1.5 L (approximately) in an earthen pot.

Mix 200g of maize meal in a water of 400ml to form a paste and pour it into a boiling water. Stir continuously to avoid lumps and a slurry porridge is obtained. For the first 5 minutes let it boil rapidly, then the heat is lowered and you allow the porridge to cook for about an additional 15-20 minutes depending on the smoothness and creamy texture desired. Add between 350-400 ml water to the cooked *mahewu* and this loosens the viscosity of the porridge. It should be allowed to cool down to a lukewarm condition, then sugar is added. The prepared *mahewu* is

kept in a warm and dark place in a cupboard to ferment for 2 – 3 days. Finally, it is stored in an earthen pot and then served cold.

4.6.5 A modified standardized recipe and method of preparation of Mahewu Beverage

The *mahewu* was prepared based on the traditional method, which was described by people from the community living in Ntambanana rural KwaZulu-Natal.

A portion of 120 grams of (local commercial maize); 1,250 mL of water; 50 g sugar. The dry ingredients were measured in grams but water was measured in millilitre. A total of nine hundred millilitre (900 ml) of water was measured and allowed to reach boiling point of (100 °C), Maize meal were reconstituted with 150 mL of water, to form a paste after which it was poured into the boiling water on the stove while on heating, a slurry porridge is obtained. The heat is reduced to a medium heat; while occasional stirring of the porridge was continued with the lid closed and was kept for the duration of the cooking period. It was cooked for about 20-25 minutes. The heat is put off and the pot was removed from the fire, after which it was occasionally stirred for about 35 to 40 minutes and it was left to stand to cool to a lukewarm temperature of 40 °C. Sugar was dissolved in 50 ml of water and this was added to the cooked porridge, which was stirred and poured into a plastic container with a perforated lid, and then it was fermented in a closed cupboard for 96 hours, (4 days). This is because of the cold weather at that of time of production. The normal fermentation period is two days but due to cold weather, the fermentation was slow.

The pH values of the samples were recorded in triplicate, and mean and standard deviation was recorded as in Table 4.1.

Table 4. 1: pH value of the mahewu sample measured in triplicate

Sample	1	2	3	Average	Standard deviation
Conventional <i>Mahewu</i>	3.56	4.56	4.57	4.56	0.0047

4.6.6 Cooking duration of Mahewu

According to the key informants, cooking technique and working time were very important factors that could affect the texture of the final product. It was emphasized that there was a

difference in cooking solely soft porridge and cooking soft porridge for *Mahewu*. There was a special technique and sequence that needed to be followed in order to achieve a quality product. During the first minutes of cooking the porridge it should boiled rapidly, then after about 10 minutes of rapid boiling, the heat should be lowered. The longer the period of cooking, the creamier the finished product. However, the longer cooking period could be a benefit a fast gelatinization, perhaps in the olden days, but with the commercial white maize, the prolonged cooking time could destroy the sensitive nutritional value of the beverage(Svihus *et al.*, 2005).

4.6.7 Culture starters and fermentation enhancers

In most communities, the fermentation of food undergoes natural fermentation processes, whereby ingredients for food preparation fermentation practices are based on the available agricultural raw materials within the domain, thus a natural fermentation starter may differ from one ethnic group to another. According to the focus group discussion, there are various starter cultures used for *Mahewu*. Culture starters within the context of food fermentation processes are microbial bacteria that are commonly called starters(Soro-Yao *et al.*, 2014, Tetra Pak, 2017). The starters contain good bacteria which are added to the food products and allowed to grow through multiplication in the food products under a controlled condition(Tetra Pak, 2017). During fermentation, bacteria produce substances that give a fermented product its unique sensory properties such as acidity (pH) taste, aroma and consistency (Tetra Pak, 2017). Study revealed that in the old days, starter culture involved the steeping of the maize kernel in water for two days. It is then crushed with a stone or a manual grinder. The crushed maize kernels were cooked until they are creamy in boiling water, then the porridge will have a sour taste and smell. The porridge is left to cool, after which it can be used as an enhancer and inoculator for the fermentation processes.

Another enhancer of *mahewu* is the use of an old *mahewu* known as *Embiliso* that has been preserved for the purpose of enhancing the fermentation of the next *mahewu*. Thus, this is added to the new *mahewu* as a starter to speed up the fermentation processes.

Furthermore, the key informants mentioned the addition of sugar which aided as a fermentation enhancer and the secondary purpose was to improve taste. The Irish potato was also mentioned as an enhancer of *mahewu* which is usually added to replace sugar in order to speed-up the fermentation processes. The Irish potatoes are dropped into the cooked porridge at a warm temperature just before it cools down, and once the *mahewu* is fermented the potatoes are

removed. It is reported that the potatoes speed up the fermentation processes such that it can ferment in less than two days. In a normal condition it was discovered that *mahewu* without sweet potatoes has a fermentation that could take about three days or more depending on the degree of sourness taste desired. But, mostly, the period for fermentation depends on the weather condition as there can be a faster fermentation under warm weather conditions than in a cold weather conditions. Natural fermentation (lactic acid) has two steps: glycolysis and Nicotinamide adenine dinucleotide (NADH) regeneration (Sadava *et al.*, 2008). During glycolysis, one glucose molecule is converted to two pyruvate molecules, producing two net Adenosine triphosphate (ATP) and two NADH (Sadava *et al.*, 2008). Bacterial and yeast are involved in the fermentation of food thus the higher the temperature, the absence of oxygen more carbon dioxide will be released by yeast, therefore forming a greater amount of bubbles. However, as soon as the temperature gets exceeded a point the rate of respiration will decrease (Akabanda *et al.*, 2014).

Microorganism for fermentation need warm enough to be healthy, but too warm will stress organisms like yeast. Also if it is too cool, the yeast will be sluggish and sleepy (Abater, 2009). Thus as temperature increases, fermentation rate accelerates. With increased fermentation rate, more aromatic compounds are produced because the metabolic intermediates are excreted from the microorganism (Blandino *et al.*, 2003, Akabanda *et al.*, 2014).

The modern enhancer is yeast, which is added when the cooked porridge, which is being cooled, reaches its lukewarm state. Furthermore, the key informants also mentioned that in the olden days Irish potatoes can be peeled dropped into the porridge for faster fermentation processes. Also, it was gathered that sweet potatoes were used for dual purposes: to boost the nutritional value of *mahewu* because they believed that sweet potato is dense in vitamins, and as well can speed up the fermentation processes which in turn will enhance the taste. This means that the rural community have their own ways of fortifying or supplementing local foods, which is believed to be low in nutrients. Thus, it can be stated that the indigenous people of old in Ntambanana did practice the science of nutrition in the course of preparing their local diets which might not have been documented. However, due to the lack of knowledge transfer to the younger generation, the practices are fading away and some would rather buy the commercial *mahewu* which they complained of having an after taste. Thus, the key informants still believe that their indigenous *mahewu* is still preferred to the commercial *mahewu*. Since 20th century nutritional status and the immune system has been a topic of study. There have been increases in peoples understanding of the immune system and the factors that regulate immune function

have demonstrated a remarkable and close agreement between host nutritional status and immunity (Keusch, 2003)

4.7 Mahewu storage and practices in the rural household

The container plays an important role in the fermenting process. Calabash, earthen pots and plastic containers were deemed most appropriate compared to stainless steel or aluminum containers. As explained, the stainless steel or aluminum containers have a cold effect, thus, they tended to slow down the fermentation processes. According to the participants, the calabash and earthen pots provided a tastier character of the beverage compared to the plastic container. These storage materials were noted to have influenced on the taste of the product.

According to the key informants and focus group discussions, due to the lack of cooling storages in the past the *Mahewu* drink was kept in a cool area, mostly the roundabout huts (house) floors that were polished using cow dung. The cow dung polish had a cooling effect in the house. However, during that era the calabash and or the earthen pots complemented the flooring. Participants. Today's times some households have refrigerators, hence the *Mahewu* is kept in them, while those households who lack the modern cooling equipment have to use plastic containers and they must make sure that the quantities are adequate for immediate use.'

Furthermore, it was reported that some of the practices that ensured the quality and shelf-life of the beverage was its protection during the processing from 'Mother Nature' in that they believed a 'thunderstorm' would cause it to separate. Precautionary measures via traditional methods were used, that include inserting a saucer or a spoon deep down into the *Mahewu* container.

4.8 Utilization of *mahewu* for food and nutrition security

It was mentioned in the focus group discussion that *Mahewu* beverage was suitable and consumed by all age groups. It is classified as a beverage and a light meal due to its unique sensory attributes, such as having a refreshing character and also the ability to quench thirst, providing wholesomeness, satisfying hunger and being convenient. Nevertheless, just like any other maize-based foods or beverages, when they are not fortified or consumed with other foods containing vitamins and minerals, then the beverage on its own could be classified as less healthy. As stated by (Tulchinsky, 2010) in sub-Saharan Africa including South Africa, nutrient deficiencies such as Vitamin A, iron and iodine and zinc are a major challenge leading to the triple disease burden. Therefore, over-reliance on compromised maize food products which are

largely starch based and consumed without food sources that are rich in essential nutrients appear to expose the most vulnerable group (young children and pregnant and non-pregnant women), consequently they are being predisposed to non-communicable diseases known as vitamin and mineral deficiencies which are preventable health challenges.

However, the traditional maize grinding process (use of stone) and fermentation have been reported to avail some of the nutritional content such as protein and other vitamins that tend to be locked-up by phytic acids (Myeni, 2015). Additionally, since synthetic nutrient is added to the fortified commercial maize meal, it provided more nutritional content as compared to the own-grown maize. However, this justification is not conclusive as the study did not conduct any comparative nutrition analysis of the commercial made *Mahewu* and the own-grown *Mahewu*. But, to my knowledge, the literature does argue the possibilities to justify the argument brought forth.

4.9 Perceived health and nutritional benefits of Mahewu consumption

When the participants were probed about the nutritional constituent of *Mahewu* drink, they understood that *mahewu* contains mainly starch and fiber. Maize constitutes the bulk of fiber (Sarwar *et al.*, 2013), and the literature also reports that fermentation of foods releases several B vitamins including niacin B3, pantothenic acid B5, folic acid B, and also vitamins B1, B2, B6 and B12 (Blandino *et al.*, 2003, Şanlier *et al.*, 2017). Furthermore, the participants were of the opinion that the consumption of *Mahewu* aided in digestion processes and relieved constipation. The literature states that natural fermentation processes preserve the food products, as well as the food nutrient, breaking down the food, thereby making it more digestible. It also creates enzymes of great importance, such as the B-vitamins, Omega-3 fatty acids, and various probiotics. In the course of fermentation, the bacteria synthesizes vitamins and minerals, making biologically active peptides with enzymes such as proteinase and peptidase, and some non-nutrients. Compounds recognized as biologically active peptides, which are produced by the bacteria and are responsible for fermentation and are also well known for their health benefits. Among these peptides, conjugated linoleic acids (polyunsaturated fatty acid), which is able to lower blood pressure, possess an anti-microbial effects, having anti-carcinogenic and anti-microbial properties, anti-oxidant, anti-microbial, antagonist and anti-allergenic properties (Şanlier *et al.*, 2017).

Mahewu is a fermented drink, and the effects of fermentation of foods (*mahewu*) have been linked with the increased digestibility of protein, improvement in nutritional and sensory quality

of maize-based foods and also a reduction in the levels of toxic/carcinogenic mycotoxins (Chelule *et al.*, 2010b). Other studies report that the fermented maize (*mahewu*) can:

- 1 Enhance the immune system, synthesizing and enhancing the bioavailability of nutrients;
- 2 Inducing symptoms of lactose intolerance (the inability to digest lactose as a result of lack of an enzyme), reducing the prevalence of allergy in vulnerable individuals.
- 3 Stimulate lactation among breastfeeding mothers is also addressed (Blandino *et al.*, 2003).
- 4 Helps in addressing diarrhea challenges i.e. it prevents and treats childhood diarrhea, and antibiotic-induced diarrhea (Parvez *et al.*, 2006).

In recent times, probiotic foods are known to be milk- (dairy-) based. However, in the old days many fermented drinks and cereal-based fermented drinks had probiotic culture (Soro-Yao *et al.*, 2014). The use of cereals, such as maize, as ingredients in probiotic food formulation as fermentable substrates for LAB, constitute dietary fiber supplementation and they have been explored (Soro-Yao *et al.*, 2014). Research has shown that some fermented cereal-based foods such as *mahewu*, which is available in southern Africa, might have probiotic potentials which are beneficial to human health. Recent research on the laboratory trial of LAB which was isolated from fermented cereal food withstood the physiological challenges posed by the gastrointestinal tract (GIT), and which might be able to colonize the GIT (Soro-Yao *et al.*, 2014). In controlled human trials (Lei *et al.*, 2006), which demonstrated that a cereal food which can be likened to *mahewu* called *umdokwe* is able to reduce or control diarrhea in children and also in adults. Water-soluble and insoluble β -glucan, arabinoxylans, oligosaccharides and resistant starch are indigestible constituents of cereal but they are fermentable dietary carbohydrates, which are used to grow probiotic LAB and could be used to realize the beneficial effects of both the probiotic and prebiotic effects (Soro-Yao *et al.*, 2014). In sub-Saharan Africa and southern Africa, there is a growing awareness of the importance and health benefits of functional foods containing probiotic. 'Probiotic' refers to a product that contains single or mixed cultures of live micro-organisms, which, when consumed improve the individual health by enhancing the microbial balance in the gut WHO (Soro-Yao *et al.*, 2014). It is reported that most of the probiotic organisms used in human food belong to the genera *Lactobacillus* or *Bifidobacterium* (Herbel *et al.*, 2013). Most often the traditional knowledge is least recognized and the most underestimated but when probed the results find no difference between traditional (indigenous) and Western or so-called scientific knowledge. The

findings of this study confirm that the traditional knowledge has science in it, although it is usually not well documented. Also, it shows that traditional foods and processes are directly excluded in designing and planning food and nutrition security programs.

4.10 Conclusion

Mahewu beverage has been identified as a common fermented non-alcoholic beverage from maize. It is consumed as a refreshing and hunger filling drink that is quite popular during the summer period. The *mahewu* drink is consumed by all household members from the weaning age to the elderly. As compared to other maize-based maize foods that are usually fortified or complemented through other foods, the *mahewu* drink is often taken with sugar and nothing else. This practice is found to be exposing the community to hidden hunger during the summer period as it seems to be a convenient food which is suitable for all age groups. Furthermore, *mahewu* is found to be a cost-effective functional food with healthy probiotics that are beneficial to the human system. However, this knowledge is not well known, thus, there is a shift towards purchasing commercial products rather than consuming the home-made foods/beverages

4.11 Recommendation

There is need for an active dissemination of information on the correct utilization of locally available food materials that are rich in essential nutrient among the rural communities. This can provide the knowledge on the importance of food supplementation or fortification at the household level, rather than a shift in dietary life style that predisposes people to fast foods, which are salty, fatty and sugary and which are less in nutritional content.

4.12 References

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CHAPTER 5:

Nutritional composition and consumer acceptability of *Moringa oleifera* leaf powder (MOPL)-supplemented mahewu, a fermented maize meal porridge

Abstract

Adequate nutrition plays a key role in optimizing human well-being and also promotes productivity of individuals and progress in any developing nation. Although in other localities mahewu could be made from other cereals such as sorghum and millet, mahewu is a staple based beverage, traditionally made from a fermented maize meal porridge in Ntambanana South Africa (SA). Several cases in the body of literature argue that food products from farmer-grown maize are often limited in amino acids and micronutrients. The present study evaluates the nutritional composition of farmer-grown maize meal and *Moringa Oleifera* leaf powder (MOLP), as an ingredient for developing MOLP-supplemented mahewu. Furthermore, consumer acceptability of MOLP supplemented mahewu beverage was evaluated using 52 panelists who voluntarily participated to rate the sensory attributes of the samples. Farmer grown maize was milled into fine flour and the maize meal and MOLP were analyzed for nutritional value. Furthermore, a control sample (0% MOLP) was prepared and also MOLP-supplemented mahewu (2%, 4% and 6%) samples were developed by substituting some of the maize meal with MOLP. All of the samples were freeze-dried and their nutritional composition was investigated. The findings show disparity in moisture content of raw materials. Ash, fat, acid detergent fiber (ADF) and nutrient detergent fiber (NDF) fibers and crude protein were high in moringa compared to maize meal. Similarly, iron calcium, copper, magnesium and manganese contents in MOLP were also high compared to the maize meal. Furthermore, with the increased concentration of MOLP in mahewu, the macronutrient and micronutrients content increased. The percentage increase revealed in the MOLP-supplemented samples: Fat: in a 2% MOLP sample was 61.49, in a 4% sample was 70.05, in a 6% sample was 59.89, respectively. Ash: in 2% sample was 28.91, in a 4% sample was 21.68, in a 6% sample was 36.74, respectively. Protein: in a 2% sample was 2.69, in a 4% sample was 10.98 in a 6% sample was 10.87, respectively. Fibers were also enhanced significantly at $p < 0.05$. Likewise, with an increase in MOLP content, the mineral content of the supplemented mahewu beverage was enhanced significantly at $p < 0.05$. The selected minerals which were highly enhanced were: calcium in a 2% sample was 350, in a 4% sample was 700 and in a 6% sample was 950, respectively. Iron was also enhanced and in a 2% sample was 105.76, in a 4% sample was 213.46 and in a 6% sample was 286.54, respectively. Copper: in a 2% sample was 40, in a 4% sample was 40 and in a 6% sample was 60, respectively. Manganese: 2% sample 28.57, 4% sample 35.71 and 6% sample 50, respectively. Followed by magnesium: 2% sample 9.09, 4% sample 18.18 and 6% sample 27.27, respectively. Therefore, MOLP had enhanced nutritional effects on the nutrient composition of MOLP supplemented mahewu samples. Notably, with increased concentration of MOLP, fat, fiber, ash, crude protein and some selected minerals increased significantly ($p < 0.05$). The implication of this study is that MOLP can be explored to improve the nutritional value of white maize food products, especially those with low iron content. The findings also revealed that 2% and 4% MLOP-supplemented mahewu was acceptable in the same manner as the reference sample. Although other sensory attributes of the 6% MOLP sample was appreciated, the color and aroma were less appreciated. The sensory evaluation reveals a need to mask 6% MOLP-supplemented mahewu beverage in a further study for better consumer acceptability.

5.1 Introduction

Malnutrition, especially micronutrient deficiencies is being recognized as a form of hidden hunger (Muthayya *et al.*, 2013a). Worldwide, micronutrient deficiency is reported as a major health challenge and a leading cause of diseases and death rate among the most vulnerable group (young children and women of childbearing age). This is common among many developing countries with more prevalence among 136 countries including India, Afghanistan as well as sub-Saharan Africa (SSA) including South Africa (Muthayya *et al.*, 2013a, Ruel-Bergeron *et al.*, 2015). Over time, maize is considered as a staple food to most SSA countries including South Africa (SA). In KwaZulu-Natal, South Africa, maize is used for preparation of foods which are consumed as: meals, snacks and beverages such as *mahewu* (Awobusuyi *et al.*, 2015a). Due to major and primary underlying causes including insufficient economic power and food hygiene, the diets of many households are being compromised for affordable food, which are mostly starch-based with insufficient essential nutrients (Oxfam, 2014). This condition incapacitates the rural population and the disadvantaged in informal settings from getting a safe and adequate diet, thus food and nutrition security is being compromised even among the self-sufficient countries such as South Africa (Oxfam, 2014). Intervention has been practiced to tackle all forms of malnutrition. Yet malnutrition is still an intractable problem, global health challenge, concern and a topic of interest for many scholars (Fayemi *et al.*, 2016).

As aforementioned, two forms of malnutrition exist. Several studies argue that both forms of malnutrition are preventable if adequate nutrition and sanitation and health care services could be accessed by all (Burchi *et al.*, 2011, Schumacher and Messmer, 2015). Nevertheless, the prevention can only be achieved where the right knowledge of food and nutrition is disseminated, applied and conscientiously adhered to, especially with reference to foods that are low in essential nutrients (staple foods). Thus, adequate nutrition remains the key to providing immunity to the human system, thereby preventing diseases, promoting and maintaining the well-being of humans (Dalei *et al.*, 2015). However, adequate nutrition does not depend on solely the quantity of food ingested, but rather both quantity and quality of the food taken, which must be balanced and nutritionally adequate.

There are six classes of food nutrients that humans derive from the varieties of foods consumed. These nutrients include carbohydrates, fat, fibers, protein, vitamins and minerals (WHO, 2014, UNICEF, 2015). The nutrients are further summarized into two broad categories, namely macronutrients and micronutrients. The former, constitute the carbohydrates, fats, protein,

fibres, and water and these are called macronutrients because the body needs them in a large amount for the supply of energy for the daily activities (Nzama, 2015). While the later constitute the vitamins and minerals, which are called micronutrients, as they are essential, yet they are only required in small amounts. An imbalance in what is consumed and what is absorbed predisposes an individual to malnutrition via any factors in the aforementioned list(Nzama, 2015).

Malnutrition, although it is often associated with under-nutrition, is also linked to over-nutrition. These nutrient-related challenges are prevalent in most developing countries, especially in sub-Saharan Africa, where micronutrients (hidden hunger) are reported to be high (Bain *et al.*, 2013). Generally, many native food habits are founded on the available agricultural raw materials. Common cereals and grains are staple crops in sub-Saharan Africa, and cereals such as maize play a vital role in the diet of many people in South Africans, and the cereals are the major sources of proteins, carbohydrates, vitamins, and minerals. Also, traditional weaning foods are based on the local staples, namely rice, maize, millet, sorghum(Nuss and Tanumihardjo, 2010). In Southern Africa, many traditional foods are prepared mainly from cereals and grain (maize). However, reliance on maize products that are mainly starch-based can expose the most vulnerable group (young children and pregnant and non-pregnant women) to non-communicable diseases known as vitamin and mineral deficiencies (Nuss and Tanumihardjo, 2010, Thompson and Amoroso, 2014). More than one type of micronutrient deficiency has been reported to exist in many settings, especially in the rural areas and among the less-privileged people in urban settings of sub-Saharan Africa (Muthayya *et al.*, 2013a). Globally, an estimated number of more than two billion people has been reported to suffer from chronic micronutrient deficiency challenges (Ramakrishnan, 2002, Tsegay *et al.*, 2014).

Various intervention programs have been introduced in many parts of developing countries, including South Africa. However, recent findings still indicate that micronutrient malnutrition with its clinical symptoms: stunting, underweight and vitamin/iron deficiency remain the most common nutritional disorders affecting one out of five children (Muthayya *et al.*, 2013b).

Further, study of women in poor resource settings still shows an inadequate intake of micronutrients particularly iron, folate, and zinc; and intake of other micronutrients that often receive less attention include the B vitamins(Torheim *et al.*, 2010). The vulnerable groups are predisposed to malnutrition through the dietary life style of monotonous diets, which lack fruits,

vegetables, and animal products (Low *et al.*, 2007, Torheim *et al.*, 2010). It is thought that consumption of *mahewu* as a filling food provides consumers with macronutrients, but it can be considered as one among other foods that are lacking in essential food nutrients which can subject consumers to nutrient-related deficiency challenges if not supplemented or diversified (Awobusuyi *et al.*, 2015a). Therefore, the focus of this study is aimed at exploring cost effective, self-reliant and more sustainable measures for the prevention of malnutrition, especially with respect to problems related to micronutrient deficiencies. *Moringa* is a promising edible plant (Jideani and Diedericks, 2014), that is popularly known to have potential in alleviating malnutrition issues. The leaves are prepared and consumed like any other leafy vegetables (Jideani and Diedericks, 2014). Moreover, it can also be dried and locally processed into powder, which can be added to foods such as soups, smoothies and beverages (Jideani and Diedericks, 2014). This study investigates the effect of MOLP on the nutritional composition of white maize meal based *mahewu* (MOLP-supplemented *mahewu*) as well as assessing the sensory attributes and consumer acceptability.

5.2 Materials and methods

The materials consist of farmer-grown white maize grain, a hammer milling machine, an organic commercial *Moringa Oleifera leaf* powder (MOLP) and white granulated sugar, tap water, a pH scale and a distilled water, digital measuring scale, four medium cooking pots with lids, four wooden spoons, four medium glass bowls and an electric stove were used. A five-point pictorial hedonic scale was used as a questionnaire to assess consumer acceptability of MOLP-supplemented *mahewu*.

5.2.1 Description of study area

The study was conducted in Ntambanana, KwaZulu-Natal (KZN), South Africa (Figure 5.1). Ntambanana was chosen as the area of study because *mahewu* is popular and *Moringa* is grown in the community. Also, the study area is predominantly faced with poverty. The land covers a vast area of 1,083 km² and the community has a population of approximately 94,194 people as per the 2007 community survey. Ntambanana is rated as one of the poorest municipalities in KZN because of its dependency on impartial economy share and other government grants. Implementation of the property rates act as a base in revenue collection in the municipality and the state provides the ability to collect rates from farmers from the 2007/2008 financial year.

There are subsistent farmers who grow vegetables, nuts and maize. The community feeds on their locally-produced maize and they alternate it with the commercial maize during the planting period. The rural population is engaged in peasant farming, and they also practice cattle farming and other agricultural activities. *Moringa Oleifera* cultivation, as a government project, is ongoing in the study area, however, due to the limited awareness it is underutilized as a food.



Figure 5. 1 Map of the study location (Jozini Area map, 2017)

5.2.2 Preamble before the preparation of mahewu samples

Farmer maize grain was cleaned by removing the extraneous materials/impurities, the maize kernel was milled into a fine flour of 0.5 mm using the hammer milling machine. Considering food safety issues, only commercial MOLP was used both for analysis and for the supplemented beverage. White granulated sugar was used to enhance the taste of the *mahewu* beverage. Medium aluminium pots were used for the cooking of *mahewu*, and plastic containers with perforated lids were used for the natural fermentation of *mahewu* in a closed cupboard and pH scale was used to measure the pH value of the *mahewu* samples.

The recipe and method obtained from the study area was modified by the development of an adjusted recipe and method, at the University of KwaZulu-Natal food laboratory on the Pietermaritzburg campus. This was achieved by several trials of scaling up and scaling down of ingredients in order to develop a standard recipe for 1 L of *mahewu* beverage as the control sample for the study. The recipe for the control sample included: 120 g of maize meal, 1,250 mL of water and 200 g of sugar which was used as an enhancer in 1 L of conventional *mahewu* beverage. Afterwards, MOLP was substituted for maize meal as calculated below, where standard recipes for MOLP-supplemented *mahewu* beverage namely: 2%, 4% and 6% was developed, details are provided in Table. 5.1. Across the world, *Moringa Oleifera* leaf powder

(MOLP) has been added to food products in several ratios such as 1 and 5% intervals. Some of the food products include snacks and main meals. In this study, conventional *mahewu* was developed as the control sample for the study. Besides the control sample, there were two percent intervals of MOLP, namely: 2%, 4% and 6%. The MOLP was incorporated into the *mahewu* beverage by substituting MOLP for maize meal. The calculations for these substitutions are detailed below. Following the calculations for these substitutions, a standard recipe for MOLP-supplemented beverage was developed for each prototype, and all the ingredients are recorded in Table 5.1.

Calculation for the substitution of maize for MOLP

Sample 1. AA 0% *Moringa*

Sample 2: AB 2% *Moringa*

$$\frac{120 \times 2}{100} = 2.4 \text{ g of MOLP}$$

Sample3: AC 4% *Moringa*

$$\frac{117.6 \times 4}{100} = 4.7 \text{ g of MOLP}$$

Sample AD 6% *Moringa*

$$\frac{115.3 \times 6}{100} = 6.9 \text{ g of MOLP}$$

Table 5. 1: Summarized recipe of *Moringa Oleifera* substitutions for 1 L each supplemented mahewu beverage for nutritional analysis

Sample prototypes in (%)	Maize in g	Moringa leaf powder in g	Water in mL	Sugar in g	Total yield in L
0%	120	0	1250	50	1
2%	117.6	2.4	1250	50	1
4%	115.2	4.7	1250	50	1
6%	112.8	7.2	1250	50	1

5.2.3 Preparation of *Moringa oleifera* leaf powder supplemented mahewu

Moringa Oleifera (MOL) - supplemented *Mahewu* preparation begins with developing the recipe as indicated in Table 5.1. All ingredients were measured and four food products were developed for the study, namely: AA 0%, AB2%, AC 4% and AD 6% and each sample of the food products contains one L of *mahewu* beverage coded as: sample AA 0%, MOLP was used as the reference sample while AB, AC and AD was supplemented with different percentages of MOLP.

To prepare *mahewu* samples, all the dried ingredients were measured as described in Table 5, the control sample was prepared by measuring 900 mL of water in a medium pot, and the water is allowed to reach the boiling point (100 °C). Maize meal was reconstituted with 150 mL of cold tap water, to form a paste after which the paste was poured into the boiling water while on heating, a slurry porridge is obtained. The heat was reduced to a medium heat, with continued stirring of the porridge occasionally with the lid closed. It was cooked for about 15-20 min. The heat was turned off, after which the porridge was occasionally stirred for about 35 to 40 min for it to cool to a lukewarm temperature (40 °C). Granulated sugar was dissolved in 50 mL of water and was added to the cooked porridge, where it was stirred and then poured into a plastic container with a perforated lid, and then it was fermented in a closed cupboard for 96 h, (4 days) because of the cold weather at the of time of the study. The pH value of the samples was recorded in triplicate, the mean and standard deviation were recorded and detailed in Table 5.2, and the same cooking method was used for preparing the other three prototypes. However, *moringa oleifera* leaf powder was measured according to the MOLP quantity against each recipe

prototype as shown in Table 5.1, MOLP was heat-treated in a suspension and was added to *mahewu* beverage before freeze drying and thereafter nutrient analysis was undertaken.

Table 5. 2: Showing the pH value of the sample as measured in triplicate

Sample	1	2	3	Average	Standard deviation
AA	5.56	4.56	4.57	4.56	0.0047
AB	4.26	4.26	4.26	4.26	0
AC	4.43	4.51	4.5	4.48	0.036

5.2.4 Rationale for the supplementation of MOLP in mahewu beverage

Although the rationale for heat treatment was explained in the literature review section 2.2.3 of this study, *Moringa* leaves and MOLP have been used in food preparation of such examples as sauces. The literature and empirical evidence show that MOLP is less appreciated because it has a raw leafy taste. MOLP has been subjected to heat temperature of about 50-100 °C for 20-25 min as a food processing measure for reducing anti-nutritional factor that might exert undesirable sensory attributes (Alidou, 2009) Boiling method as a food processing method was adopted in this study to in order to suppress the raw leafy taste of MOLP. MOLP was heat treated and added to the *mahewu* after the porridge had been fermented prior to consumption. This was done where MOLP was measured based on the ratio of recipe for each prototype, and it was subjected to heat treatment where it was poured into a pot and subjected to a low temperature of heat until boiling point at 100 °C. The three prototypes, followed the same procedure as the recipe that is described in previous section. Also, the same method of preparation was adopted for the supplemented *mahewu* beverage, however, with different a measurement of maize meal and corresponding percentages of MOLP as indicated in Table 5.1. The percentage of *moringa* was calculated and substituted for maize meal. Thus, the corresponding value of *Moringa* in grams was substituted for maize meal as detailed in Table 5.1.

5.2.5 Moisture content analysis

The empty containers were weighed and recorded, samples were poured into the empty containers and weighed again, and all information was recorded as detailed in Table 5.3, the samples were placed in the freeze drying machine (lyophilizer) bench top. Each set of sample took 8-9 days to complete the freeze drying processes because *mahewu* is made up of 88 to 90% moisture. After samples were freeze dried, the moisture and the solid content were calculated and are detailed in Tables 5.3 and 5.4. Following this, there was the crushing of samples into powder form, using a (crucible), and afterwards all samples were duplicated into 12 samples including the raw materials for this study. The samples were all poured into a zip lock bag before the nutritional analysis.

Table 5. 3: Weight of empty container and samples before freeze-drying.

Sample Identification	Weight of empty container	Weight of container and sample before. Freeze drying
0%	37.1	964.2
2%	37.3	911.6
4%	113.9	938.9
6%	116.1	971.4

Table 5. 4: Detailed weight of sample, moisture content and total solid of the liquid mahewu before freeze-drying of MOLP supplemented sample

Sample identification (ID)	W1	W2	W3	Total moisture content of 1 L <i>mahewu</i> beverage in (%)	Total solid content in 1 L <i>mahewu</i> beverage in (%)
0% (control).	37.1	964.2	123.02	90.73%	12.76
2%	37.3	911.6	133.54	90.17%	14.65
4%	113.9	938.9	207.59	88.64%	22.12
6%	116.1	971.4	215.30	88.40%	22.16

The moisture content and the solid content of the samples were calculated according to the Association of Analytical Communities (AOAC) official method 934.01, (AOAC, 2003).

The formula for calculating moisture content (%):-

$$\frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where W_1 is the weight of the initial sample. In this equation, W_2 is the weight of initial sample before freeze-drying and W_3 is the weight of dry sample.

The Formula for solid content (%) = $\frac{W_3}{W_2} \times 100$

5.2.6 Procedures for nutritional Analysis

After the freeze drying of all samples into a crucible substance, the supplemented samples with the raw materials (maize meal and MOLP) were duplicated and 12 samples were packed into airtight zip lock plastic bags for nutritional analysis as described below. Following the analysis, all the moisture content for all the crucible samples were measured according to the AOAC Official Method 934.01 (AOAC, 2003). All samples were dried at 95 °C for 72 hour in an air-circulated oven. The weight loss of the samples was used to calculate the moisture content and the following equation was used to calculate the moisture content in percentage:

% *Moisture*

$$= \frac{(\text{mass of the sample + dish}) - (\text{mass of sample + dish after drying})}{(\text{mass of the sample + dish}) - (\text{mass of petri dish without the lid})} \times 100$$

Fat: The fat content of the samples was determined based on Soxhlet procedure, using a Büchi 810 Soxhlet Fat extractor (Büchi, Flawil, Switzerland) according to the AOAC Official Method 920.39 (AOAC 2003). Petroleum ether was used for extraction. The percentage crude fat was calculated using the following equation:-

$$\% \text{ crude fat} = \frac{\text{Mass of beaker + fat} - \text{mass of beaker}}{\text{sample mass}} \times 100$$

Protein: The content of protein in the samples was measured, using LECO Truspec Nitrogen Analyzer (LECO Corporation, St Joseph, Michigan, USA) using the AOAC official method

990.03 109 (AOAC, 2003). The reference and supplemented samples were duplicated and placed into a combustion chamber at the value of 950 °C with an autoloader. The following equation was used to calculate the percentage of protein in the samples: % *crude protein* = % *N* × 6.25.

The mineral content of the samples was determined as ash according to the AOAC official method 942.05 (AOAC, 2003). This happened where the samples were weighed and placed in a furnace at 550 °C overnight. The minerals remained as a residue of ash in the crucibles state after the volatilization of the organic matter from the samples. The following equation was used to determine the percentage of ash that was found in the samples:

$$\% \text{ ash} = \frac{(\text{mass of sample + crucible after ashing}) - (\text{mass of pre-dried crucible})}{(\text{Mass of sample + crucible}) - (\text{Mass of pre-dried crucible})} \times 100$$

Fiber: Fiber was determined as neutral detergent (NDF). The NDF samples was analyzed using Dosi-Fiber machine (JP Selecta, Abera, and B, span), according to the AOAC Official Method 2002.04 (AOAC, 2002)

Mineral element: Individual mineral element includes: calcium, magnesium, potassium, sodium, phosphorus, zinc copper, manganese and iron were all analyzed using the Agricultural Laboratory Association of Southern Africa (IALASA) method 6.5.1. The preparation of samples was done in University of KwaZulu-Natal pietermarisburg campus were all samples were prepared and freeze dried using a freeze drier (Edwards, High Vacuum International, Sussex, and, England). The samples were ashed overnight at 550 °C in a dry heat. The samples were dissolved in HCl and HNO₃ added to the sample which were analyzed using an atomic absorption spectrophotometer. The calcium and phosphorus were determined using an (Analytic Jena Spekol 1300 spectrophotometer (analytic Jane AG, Achtung Germany. Iron was determined with the Varian spectra atomic absorption spectrophotometer (Varian Australia Pty Ltd, Mulgrave, Australia), the zinc with the GBC 905AA spectrophotometer (GBC Scientific Equipment Pty. Ltd, Dandenong, Victoria, Australia).

5.2.7 Sensory evaluation procedures

Sensory evaluation is an experimental design, which was conveniently adopted for this study to determine the consumer's sensory attributes and acceptability level of MOLP supplemented *mahewu* beverage. Committees, organizations within the various professionals such as the Institute of Food Technology and American Society of Food Tasting have declared a general and acceptable endorsed definition of sensory evaluation. Sensory evaluation is a scientific discipline that is used to evoke, measure, analyze and interpret the reactions to the attributes of food products as they are perceived by the five senses, such as sight, smell, taste, touch and hearing which reduces the potential for bias (Stone and Sidel, 2004, Lawless and Heymann, 2010).

The current study intends to assess the consumer sensory attributes and acceptability of MOLP supplemented *mahewu* beverage. Five-point hedonic scale 1 = Very bad, 2 = Bad, 3 = Average, 4 = Good, 5 = Very good (Appendix L) was used for the panelists to determine their sensory attributes and the overall acceptability.

The services of trained research assistants were used to administer questionnaires. Five point hedonic scale questionnaires were written in English, (Appendix P) and then interpreted to IsiZulu by two of the research assistants, who fluently speak and write the IsiZulu language. Furthermore, they were further crosschecked by another research assistant to be ensure of the clarity and correct context in the language of the community (IsiZulu; Appendix L). The field workers were trained for two days and were monitored by the researcher (i.e. myself) during data collection exercise and setting up of the venues for sensory evaluation and focus group discussions. Participation in the study was purely voluntary as such, all participants signed consent forms. In addition, they were verbally reminded before the beginning of each study session.

i. Sampling technique and population for sensory evaluation

After the nutritional analysis of the control sample and MOLP-supplemented *mahewu* samples, sensory evaluation for the supplemented samples was conducted in the study area using volunteers who were *mahewu* consumers. Letters were sent out through the research assistant, key informants and through the pupils in primary school. A total of 52 household representatives who were *mahewu* consumers and they were willing to participate in the sensory evaluation under consideration. Hence a convenient sampling method was used for the sensory evaluation. .

ii. The preparation *Mahewu* sample for sensory evaluation procedures

Four L for the reference sample and 4 L for each of the MOLP supplemented *mahewu* beverage (2, % 4% and 6%) were prepared according to the recipe and that method that was developed earlier in Appendix E and Appendix F. To ensure that *mahewu* beverage samples were culturally acceptable by the participants, the *mahewu* beverage for the sensory evaluation was prepared at the research site by two women from the community who are experienced in *mahewu* making. This was achieved as the women were shown how to measure all the ingredients and also how to add the MOLP to make the supplemented *mahewu* beverage.

iii. Coding and serving order and sensory evaluation set-up

To avoid any bias with the label of samples, a table of random numbers was assigned and each sample had a unique three-digit code using a table of random permutation of nine as detailed in Appendix D. The samples were tested in a randomized order, starting from the left and moving to the right. Randomization of the serving order was conducted using a table of random Permutations of Nine. To prevent panellists from influencing each other's responses, panellists were made to sit apart with their backs turned to each other. Before the commencement of the sensory evaluation, panellists were asked to sign the informed consent (see Appendix K) which was thoroughly explained to participants in the local language of IsiZulu before the form signing stage. All participants were provided with a cup of mineral water, serviette, and four samples which consisted of about a heaped table spoon or 12-12.5 mL, as a sip or two sips of each of the four samples were poured into a small disposable cup. A five-point pictorial hedonic (detailed in Appendix L and Appendix P), was used to collect data for sensory evaluation of *mahewu* prototypes. A five-point hedonic scale was used to indicate whether consumers disliked the sample by way of: Very Bad, Bad, Average, Good, and Very Good. Four sensory attributes which is color, aroma, mouth feel, taste and overall acceptability of each sample were assessed.

5.2.8 Ethical Clearance

Permission from the department of agriculture under the auspices of the Luwamba Center in Ntambanana was granted before the study began. Likewise the University of KwaZulu-Natal Humanities, and Social Science Research Ethics Committee issued an ethical clearance number

HSS/0559/01016 before conducting the study. Also consent form was filled by the participant to show their willingness before the commencement of the sensory evaluation.

5.3 Results and discussion

The proximate profile of maize meal and MOLP is presented in Table. 5.5, while the individual mineral composition of the raw materials (maize meal and *Moringa Oleifera* leaf powder) is presented in Table 5.6. Furthermore, the results for the MOLP supplemented *mahewu* is presented in Tables 5.7 and 5.8.

Table 5. 5: The proximate Profile of maize meal and Moringa Oleifera leaf powder

	Raw material (100% /dry matters)	
	Maize meal	Moringa
Moisture	9.43 ± 0.28	7.83 ± 0.00
Ash	1.38 ± 0.05	13.08 ± 0.04
Fat	4.16 ± 0.01	8.38 ± 0.63
ADF	5.91 ± 0.09	15.65 ± 0.06
NDF	17.20 ± 0.81	19.50 ± 1.82
Crude protein	9.88 ± 0.16	26.28 ± 0.11

Values indicate the mean and standard deviation with significant difference $p < 0.05$

In Table 5.5, the result ranges from 9.43 ± 0.28 Moisture content, 1.38 ± 0.05 for ash content, 4.16 ± 0.01 for fat content, 5.91 ± 0.9 ADF content 17.20 ± 0.81 for NDF and 9.88 ± 0.16 for Crude protein content. Likewise, in Figure 5.2, the MOLP nutritional profile ranges from 7.83 ± 0.0 for Moisture content, 13.08 ± 0.04 for Ash content, 8.38 ± 0.63 for fat content, 15.65 ± 0.06 ADF content 19.50 ± 1.82 NDF content and 26.28 ± 0.11 for Crude protein content, respectively. With the exception of moisture content of *moringa*, all other nutrients in MOLP were high in profile compared to maize meal, thus, both materials showed a good blend for the development of a nutritious beverage (*Mahewu*). The findings in Table 5.5 reveal Moisture, Ash, and fat, ADF, NDF and crude protein content in both maize and MOLP. Besides the moisture content of *moringa*, which showed a lower moisture content than in maize meal, the study shows that MOLP had high nutritional value which is recorded against Ash, Fat, ADF, NDF and crude protein when compared to the maize meal profile. The result for the proximate profile of the two raw materials (maize meal and *Moringa Oleifera* leaf powder) are detailed in

Table 5.5, The proximate profile: Moisture, ash, fat, ADF, NDF and Protein for MOLP was high compared to that of maize meal, thus *Moringa* can be used to enhance any maize-based food products such as *mahewu*. Similarly, the mineral profile for MOLP and maize meal reported in Table 5.6 was also observed to be higher compared to maize meal. This implies that MOLP has the potential for enhancing the mineral inadequacies in maize-based food products, which can be explored in staple foods to tackle malnutrition challenges.

Table 5. 6: Mineral element composition of raw maize meal and *Moringa Oleifera* leaf powder

Mineral	Maize meal	Moringa
Calcium	0.03 ± 0.02	2.90 ± 0.01
Magnesium	0.09 ± 0.00	0.64 ± 0.01
Potassium	0.29 ± 0.01	1.44 ± 0.01
Sodium	0.00 ± 0.00	0.04 ± 0.00
K/Ca +Mg	0.86 ± 0.11	0.19 ± 0.00
Phosphorus	0.24 ± 0.01	0.26 ± 0.00
Zinc	20.50 ± 2.12	27.50 ± 10.61
Copper	1.00 ± 0.00	6.50 ± 0.71
Manganese	6.00 ± 0.00	75.00 ± 1.41
Iron	19.50 ± 3.54	1091.50 ± 6.6

Values indicate mean and standard deviation with significant differences $p < 0.05$)

The individual mineral profile for maize meal and *Moringa Oleifera* leaf powder (MOLP) is revealed in Table 5.6., with a significant differences of $p < 0.05$ across the mineral profile.

Table 5. 7: Macronutrient composition of MOLP supplemented mahewu samples [Dry mass basis (db.)]

					Percentage increase		
					2% <i>Moringa</i>	4% <i>Moringa</i>	6% <i>Moringa</i>
Moisture (g/100 g)	4.53 ± 0.65 ^a	2.07 ± 0.15 ^b	2.15 ± 0.03 ^b	5.02 ± 1.56 ^a	-54.3046	-52.5386	10.8168
Ash (g/100 g)	1.66 ± 0.17 ^a	2.14 ± 0.59 ^a	2.02 ± 0.04 ^a	2.27 ± 0.06 ^a	28.9157	21.6867	36.7470
Fat g/100 g)	1.87 ± 0.10 ^a	3.02 ± 0.08 ^b	3.18 ± 0.06 ^b	2.99 ± 0.07 ^b	61.4972	70.0535	59.8930
ADF (g/100 g)	8.45 ± 0.28 ^a	7.20 ± 1.12 ^b	6.95 ± 0.28 ^b	7.44 ± 0.78 ^b	-14.7929	-17.7515	-11.9527
NDF (g/100 g)	11.70 ± 0.36 ^b	11.22 ± 0.36 ^a	11.47 ± 0.08 ^a	12.03 ± 0.74 ^b	-4.2735	-2.5641	2.5641
Crude protein g/100 g)	8.92 ± 0.11 ^a	9.16 ± 0.28 ^a	9.90 ± 0.05 ^b	9.89 ± 0.16 ^b	2.6906	10.9865	10.8744

Means values with different superscript in each row differ significantly (p < 0.05). (Duncan's Multiple Range test was used to identify significant difference, p < 0.05)

In Table 5.7, the result reveals that there is an increased percentage of in the nutritional composition of the MOLP-supplemented *mahewu* beverage, and a significant difference in the nutritional profile was observed at ($p < 0.05$). This was observed across the proximate characteristics of Fat, ADF, NDF and crude protein content. The fat content of *Moringa* was significantly enhanced compare with the reference sample. Therefore, this study confirms that there is significant potential in MOLP which could be explored for enhancing the nutritional content of maize-based food products such as *mahewu* for the food and nutrition security of consumers of *mahewu* as filling or weaning food.

Table 5. 8: Micronutrient composition of MOLP-supplemented mahewu samples [Dry basis (db.)]

Mean \pm SD

Mineral	Control	2% <i>Moringa</i>	4% <i>Moringa</i>	6% <i>Moringa</i>	Percentage increase		
					2% <i>Moringa</i>	4% <i>Moringa</i>	6% <i>Moringa</i>
Calcium(m/100 g)	0.02 \pm 0.00 ^a	0.09 \pm 0.01 ^b	0.16 \pm 0.00 ^c	0.21 \pm 0.00 ^d	350	700	950
Magnesium(m/100 g)	0.11 \pm 0.00 ^a	0.12 \pm 0.00 ^b	0.13 \pm 0.01 ^c	0.14 \pm 0.00 ^d	9.09	18.18	27.27
Potassium(m/100 g)	0.35 \pm 0.03 ^a	0.38 \pm 0.01 ^b	0.41 \pm 0.01 ^c	0.41 \pm 0.00 ^b	8.57	17.14	17.14
Sodium(m/100 g)	0.01 \pm 0.00	0.01 \pm 0.00	0.01 \pm 0.00	0.01 \pm 0.00	0	0	0
K/Ca +Mg9(m/100 g)	0.9 \pm 0.03 ^a	0.68 \pm 0.01 ^b	0.57 \pm 0.02 ^c	0.47 \pm 0.00 ^d	-24.44	-36.66	-47.78
Phosphorus(m/100 g)	0.26 \pm 0.01 ^a	0.26 \pm 0.00 ^b	0.26 \pm 0.00 ^b	0.26 \pm 0.01 ^a	0	0	0
Zinc(mg/kg)	28.50 \pm 3.54 ^a	27.00 \pm 1.41 ^b	25.00 \pm 0.00 ^c	25.00 \pm 0.00 ^c	-5.26	-12.28	-12.28
Copper(mg/kg)	2.50 \pm 0.71 ^a	3.50 \pm 0.71 ^b	3.50 \pm 0.71 ^b	4.00 \pm 0.00 ^c	40	40	60
Manganese(mg/kg)	7.00 \pm 0.00 ^a	9.00 \pm 0.00 ^b	9.50 \pm 2.12 ^c	10.50 \pm 0.00 ^d	28.57	35.71	50
Iron(mg/kg)	26.00 \pm 2.83 ^a	53.50 \pm 0.71 ^b	81.50 \pm 4.95 ^c	100.50 \pm 9.19 ^d	105.76	213.46	286.54

Mean values with different superscript in each row differ significantly ($p < 0.05$). (Duncan's Multiple Range test was used to identify significant difference, $p < 0.05$)

Table 5.8 presents the mineral composition of MOLP-supplemented beverage' which is significantly different at $p < 0.05$. The nutritional characteristics of the supplemented beverage was increased in mineral content as percentage of MOLP increases, compared to the control, the increase was noticeable across the mineral content of the three prototypes. In calcium, k ca/+mg, magnesium, potassium, sodium, phosphorus, zinc, copper, manganese and iron content which was nutritionally enhanced. These findings reveal that there is a great significant potential of MOLP which can be explored in order to enhance the nutritional content of *mahewu*. This could cater for the wellbeing of consumers who use *mahewu* for young children and MOLP can be a cheaper yet nutrient dense food compliment compared to other weaning food. This investigation confirms that MOLP has positive effects on enhancing the mineral characteristics of *mahewu* beverage and therefore can be used in other staple-based food preparations.

5.3.1 Data Analysis

The Statistical Package for Social Sciences IMB (SPSS statistic 24) version 2016 was used for both the quantitative and the descriptive data where statistical analysis was conducted. All samples were analysed in duplicate. The duplicated data were obtained and subjected to an Analysis of Variance (ANOVA). The post hoc test, Duncan's multiple Range test, was used to identify a significant difference which was recorded at $p < 0.05$.

5.3.2 Macronutrient content in the raw materials

Table 5.5 shows that white maize meal and MOLP moisture content was 9.43 ± 0.8 and 7.83 ± 0.004 , respectively. The white maize meal moisture content in this study is slightly lower than in the study reported by (Nuss and Tanumihardjo, 2010). In the present study it is identified that moisture content of maize meal can be associated with poor post-harvest practices such as proper or improper storage of either the maize kernel or the maize meal. According to the World Food Program (WFP), the normal moisture levels of Maize meal should be within the range of 10-14%, although 14% is being specified for the coarsely grounded Maize materials, and 10% is being specified for the fine flour (WFP, 2011, Gwirtz and Garcia-Casal, 2014).

The moisture content of MOLP was observed as being lower than the moisture content of maize, as both raw material have different moisture content. However, similar result was reported by a study conducted by Shiriki, who recorded 6.50 ± 0.02 for moisture content (Shiriki *et al.*, 2015). Table 5.5 shows that the moisture content of MOLP was 7.83 ± 0.004 and this finding is lower than the results in (Madukwe *et al.*, 2013), but slightly higher than the study reported by Shiriki

(2015). However, this study can still be compared to the study reported by (Okiki *et al.*, 2015) in which the moisture content was recorded as being 7.88 ± 0.29 . Although there was a slight difference which could be associated with climatic condition and processing methods. Therefore, the proximate analysis of the *Moringa* used for this study was free from a high moisture content. Hence, it is a dried leaf powder, which suggest a longer shelf life. This confirms that once *moringa leaf* powder is dried, it can be stored in an air tight container outside the refrigerator for six months yet it will still be free from contaminants and spoilage, as in the aforementioned literature (Potisate *et al.*, 2015). Therefore, it can be argued that the lower the moisture content of any vegetable, e.g. MOLP, the longer it will store.

Also an added advantage, is it is a cheaper, accessible and a readily available supplement for the less privileged population who might not have access to a refrigerator or to long-term storage space for food (Fuglie, 2001). Furthermore, the more moisture in a food substance, the less dense are the nutrients (McClements, 2017). Since the moisture content of the raw material is low, MOLP becomes high in nutritional density, of both macro- and micronutrients. (Saha *et al.*, 2012). Hence, dry matter of the *Moringa Oleifera* leaf powder in this study was found rich in nutrient, therefore, MOLP can be used for food supplementation among communities where malnutrition is highly prevalent.

Ash

The ash content of the maize was found to be low with a mean value ranging from 1.3 ± 0.05 for maize meal, and MOLP was 13.08 ± 0.63 . The Ash content of *Moringa Oleifera* was found to be higher compared to the study reported by (Moyo *et al.*, 2011). However, the ash content of foods has been studied on Maize meal, but this result showed a higher ash content in the maize meal than in the study result reported by (Onyango, 2014). In a proximate analysis, ash refers to total mineral content found in a food (Hall, 2007). It is confirmed that the ashing of food samples is the first step in preparing samples for analysis of specific minerals. According to Marshall (2010), the ashing of raw materials is usually undertaken to check the mineral content, as some foods are high in certain minerals. As a result of ashing, the minerals content was evaluated and the mineral profile is detailed in Table 5.5. Ash comprises of all inorganic substances which are present in food (Marshall, 2010). Ash is the leftover residue that is seen after high heat is subjected and a complete oxidation of inorganic matter in the food; water and organic materials such as fats and protein are all removed. Ash also includes compounds with essential minerals such as calcium and potassium, although ash is also known to include some toxic substances

such as mercury (Baker, 2015). However, there is limited information about toxic substances in MOLP. Therefore, the ash content of the raw materials is very important because it has been identified that the amount of minerals can be determined by the physiochemical properties of foods. This suggest that the higher the ash content of a food, the higher the mineral content. Thus, the high content of (MOLP) suggests that certain mineral contents are high and this supports the fact that MOLP makes an adequate food plant for mineral-deficient populations. It is noteworthy that the amount of minerals can help to retard the growth of microorganisms that are present in a food(Hall, 2007). Thus, *Moringa Oleifera* powder can be stored in an airtight container for a longer duration without refrigerating it. This makes it a whole food supplement for the less-privileged who might not have access to animal protein or the expensive and synthetic minerals and vitamins food supplements.

Fat

Fat content ranges from 4.16 ± 0.09 for maize and 8.38 ± 0.63 for *Moringa*. Besides carbohydrate and protein, fat is the next largest nutrient in the nutritional component of maize. However, the maize meal used for this study had a low fat content compared to that of MOLP, nevertheless, the mean value of the fat content of maize meal can be likened to the study of (Ijabadeniyi and Adebolu, 2005). Although the maize meal fat content in this study was slightly higher than that of the study reported by (Nuss and Tanumihardjo, 2010), maize has been reported to contain fat-soluble vitamin such as vitamin A, D E and K. However, it is noted in the literature that carotenoids are largely obtained from yellow maize, which should surely constitute the genetically-controlled majority that ought to be destined for human consumption, rather than the white maize; but the yellow maize is used as animal feed. Thus, in this study, white maize was used as the raw material (Zhang *et al.*, 2011, Francais, 2017).

Fat was observed to be higher in MOLP with a mean value of 15.65 ± 1.82 . This is supported by the study conducted by (Jed and Fahey, 2005), who affirm that dried *Moringa* leaves contain 17 fatty acids including linolenic acid. Furthermore, a study in the body of literature reports that the polyunsaturated fatty acids that are present in *Moringa Oleifera* have more benefits in human and animal nutrition. Polyunsaturated fats comprise of omega-3 fats, and omega-6 are types of fats that are known to reduce triglycerides and are a type of fat that is present in human blood (Moyo *et al.*, 2011). Thus, the present study suggests that MOLP can be explored with respect to food preparation or as a supplement which can offer healthy fats for both human and animal nutrition. MOLP can provide healthy fats and perhaps more so than animal fats; omega 3 and mega 6 are noted to be beneficial and especially for those people who are on low fat diets (Moyo

et al., 2011). To ensure food and nutrition security, MOLP can be incorporated into food preparation, including beverages such as (*Mahewu*) for food and nutrition security.

Fiber (ADF and NDF)

Fibers are healthy, especially for those who struggle with constipation or irregular expulsion of fecal materials because dietary roughages are known to promote the movement of unwanted material through the digestive system (Dhingra *et al.*, 2012). The fiber content of the *Moringa* showed a higher fiber content than there is in Maize meal.

Neutral detergent fiber (NDF) consists of all the undigested roughages in a diet. These include: hemicellulose, cellulose, lignocellulose, and lignin. NDF characterizes the total bulk of the food; the higher the NDF, the lesser the quantity food that can be consumed by humans and animals. However, according to (Dhingra *et al.*, 2012), the NDF level that is too low might predispose an individual to stomach upsets.

Acid detergent fiber (ADF) is a subgroup of NDF, which includes cellulose, lignocellulose, and lignin. Acid detergent fiber is the least digestible portion of the food, thus, a higher ADF equals lower calories. Foods with a high ADF may be poorly accepted. Dietary fiber consists of the leftover plant cells such as hemicellulose, cellulose, non-carbohydrate component lignin, oligosaccharides, pectin's, gums and waxes, which are not digested by the alimentary enzymes of human beings (Dhingra *et al.*, 2012)

Food products that are rich in fiber, especially cereals, fruits, nuts and vegetables have been known to have promising effects on wellbeing since their consumption has been associated with a decrease in the probability of colon illness (Dhingra *et al.*, 2012). ADF and NDF are abbreviations that connote types of fiber found in food products. ADF means Acid Detergent Fiber and NDF is a neutral detergent fiber. Both fibers are dietary 'roughage' which may not be a nutrient because to its impact on the digestive system of animals, whereas fiber is somewhat of an important component of human diets (EUFIC 2005). Fibers are transported through the body without being absorbed, therefore, it is the main reason for its importance in a healthy dietary plan. The fiber is composed of all the edible parts of plant which are ingested but it is neither digested nor absorbed in the small intestine but, rather, it passes into the large intestinal tract (Dhingra *et al.*, 2012). The reason is that fibers are resistant to hydrolysis and enzymatic digestion. ADF is the amount of insoluble fiber in the plant cell which comprises cellulose and lignin. ADF also includes soluble fiber (Test Diet, 2017). On the other hand, Neutral Detergent Fiber (NDF) refers to the amount of insoluble fiber in human nutrition (Hall, 2007).

Even though the exact figure of crude fiber cannot be obtained, the Acid Detergent Fiber value can be subtracted from the Neutral Detergent Fiber value in order to obtain a figure that is close to that of the crude fiber (CF) of any food product. Generally, dietary fibers include: non-starch polysaccharides (e.g. cellulose, hemicellulose, gums, and pectin), oligosaccharides (e.g. inulin), lignin and associated plant materials such as waxes and subring. Furthermore, dietary fiber also includes a type of resistant starch which is found in pulses and is also partly found in milled grains. Since fibers are not digested in the small intestine, they are transported to the large intestine as undigested waste materials which help in easing defecation

Dietary fiber

Dietary fibers are often classified according to their solubility as such they are categorized into soluble or insoluble fibers. Although both types of fiber are found in certain amounts in all fiber-containing foods, the good sources of soluble fiber include: whole grain cereals, whole meal bread, legumes, fruits and vegetables including *moringa oleifera*. Insoluble fibers have been studied as types of fibers that have great benefits to those who are challenged with constipation or irregular expulsion of fecal materials. Therefore, dietary roughage has been researched to promote the removal of unwanted material through the digestive system and also they are known to increase the bulkiness of stools.

Compared to maize meal, *Moringa Oleifera* leaf powder (MOLP) was found to have a high content of Acid Detergent Fiber and Neutral Detergent Fiber (ADF/NDF) than in the maize meal. Since total fiber forms part of the component of carbohydrates, in food analysis this suggests that aside the other nutrients that are present in MOLP, it is a good source of carbohydrates which is an important element of the macronutrients in human and animal nutrition. Thus, fiber is identified as being essential and beneficial in humans because it is fiber works to keep the colon functioning smoothly which in turn promotes bowel system regularity (Faber *et al.*, 2010). Studies also confirm that fibers aid in lowering cholesterol levels, which prevents heart disease, manages a healthy and overall body weight. An increased fiber consumption, especially from vegetable sources in the amount of about 6 g daily among men and women aged 50-70 years was linked with a 25% reduction of ischemic heart disease mortality (Mgbemena and Obodo, 2016). *Moringa* is a good source of food plant for enhancing fiber content in any maize-based food products, especially beverages such as *Mahewu* and other starch-based food products.

Protein

The protein in the maize meal was found to be low compared to the *Moringa Oleifera* leaf powder, which was found to be high in protein content. Maize protein content has a mean value of 9.88 ± 0.81 which is lower, but it is higher in *Moringa Oleifera* with a mean value of 26.28 ± 0.11 . Although the present study results show a higher content of protein in the maize meal than the results study of the study reported by (Onyango, 2014). This could be due to environmental factors and the processing methodology. Crude protein is one of the major food nutrients that are essential in building and replacing worn out or broken tissue, and it is essential for growth, muscle, skin, bone, cartilage. *Moringa* has been reported to have all the essential food nutrients including amino acid (Oyeyinka and Oyeyinka, 2016).

Protein is one of the macronutrient needs of humans it is required by the body in large quantity. It is essential for building up of body including the replacement of dead cells, growth, development, replenishment of lost blood (Alaverdashvili *et al.*, 2015). It is argued that proteins in forms of hormones, enzymes, and antibodies can assist in promoting healthy metabolic and immune processes. Also, when carbohydrate is exhausted and fat levels becomes low in the human body, protein help to supply energy for the body.

The literature report that *mahewu* is consumed by many locality in the southern Africa (Awobusuyi, 2015). Thus for proper nutrition, this study suggest that the consumption of *mahewu* as a meal should be consumed along with nutrient dense food supplements such as MOLP which have adequate protein and other essential minerals and vitamins (Moyo *et al.*, 2011). This implies that the excess or inadequate intake of protein changes the basic compound of the body and ultimately affects health. Therefore, to prevent and to address malnutrition and hidden hunger and their health-related issues, the results of the present study suggest that MOLP is a potential supplement in most cereal- and starch-based food products and especially *Mahewu*. Thus, the present study reveals that the application of mixed plant protein (cereal and vegetable protein) is suitable in the formulation of nutritious beverage (MOLP. supplemented *Mahewu*) for food and nutrition security of people who cannot afford expensive food sources of protein and essential vitamins and minerals.

5.3.3 Mineral composition in the raw material

Minerals in this context refer to inorganic compounds, which exist in a food, and they constitute essential nutrients that are required by living organisms. Seventeen minerals are identified as

essential for normal metabolic activities, and seven of them include: iron (Fe), zinc (Zn), copper (Cu), calcium (Ca), magnesium (Mg), iodine (I), and selenium - and they can be lacking in the human diet (Nuss and Tanumihardjo, 2010). The present study is focused on modifying an indigenous beverage with mineral-rich food sources of MOLP which has been explored for nutritional benefits in staple foods. Major minerals have been categorized into two major minerals which are needed in quantity greater than 100 mg per day, and the trace minerals that are required in amounts of not more than a few mg per day (Nuss and Tanumihardjo, 2010). In the present study, all of the mineral content presented in Table 5.6, was found to be higher in MOLP than in Maize meal. The highest mineral content in *Moringa* was calcium with a mean value of 2.90 ± 0.01 and iron which showed a mean value of 1091.50 ± 6.6 , Manganese 75.00 ± 1.14 , and Zinc 20.50 ± 2.12 and 27.50 ± 10.16 , respectively of which the same mean value was found to be lower in Maize meal with a significant difference of $p < 0.05$. The mineral content in the present study is higher than that which reported in the study by (Moyo *et al.*, 2011). The present study confirms that *Moringa* has a higher content of most essential minerals which can be a good source of essential minerals *Mahewu* and is a good supplement in foods that lack essential vitamins and minerals in both human and animal nutrition.

Table 5.6 shows the individual mineral profile characteristics of maize meal and MOLP. The mineral content of calcium for the Maize meal was found to be lower compared to MOLP. The Mean values of calcium for both raw materials ranges between 0.03 ± 0.02 for maize and 2.90 ± 0.01 for *Moringa Oleifera* leaf powder which had the highest value. It is reported in the literature that MOLP contains an appreciable content of calcium (Madukwe *et al.*, 2013). The result in Table 5.6 shows that MOLP is higher in calcium content than Maize meal.

Calcium has been identified among the major mineral in human and animal's nutrition for optimum wellbeing. According to Hill, (2008). An average adult is made up of 800 to 1,300 g of this element, and also 99% of calcium is found in the bones and teeth of humans only. Only 1% is deposited in the blood and muscles (Hill, 2008). The calcium concentration is controlled by several hormones and by vitamin D (Hill, 2008, Maresz, 2015). Furthermore, when the amount of calcium becomes too low in the blood, then the calcium reserves in the bones are used to restore levels to the normal range. Therefore, it is necessary that calcium nutrient-rich food sources should be included in the human diet and most especially the diet of those who are vulnerable to calcium deficiency challenges. Likewise, when calcium is too high in the blood, then more calcium is deposited in the bones as more calcium is expelled by the kidneys. Furthermore, an excess of calcium intake can be toxic to humans and causes heart disease

(Maresz, 2015). About 12,000 mg of calcium per day and above are considered to be toxic (Hill, 2008). Therefore, to avoid over-nutrition, food sources that might be rich in calcium should not be consumed along with substantial amounts of *Moringa* as *Moringa* is a good source of substantial amounts of calcium (Dhakar *et al.*, 2011b). However, incorporating *Moringa* into a diet such as regular vegetable or supplement especially in maize-based food products can be beneficial in enhancing the nutritional adequacies of calcium in white maize-based food products and other calcium-deficient foods.

Table 5.6 shows the Magnesium content of Maize as 0.09 ± 0.00 and the mean value was low compared to *Moringa Oleifera* that was found to be as high as 0.64 ± 0.01 . The Magnesium content of *Moringa Oleifera* leaf powder was higher than that of Maize. However, it is affirmed that magnesium can function in the body as calcium in several ways. Literature declares that 60% of Magnesium is also present in the teeth and bones and only 40% is mostly located in the muscles (Hopkins, 2017).

Magnesium is reported to be the second most ample positively-charged element that is found within the cells. This implies that Magnesium is exceptionally important for health promotion, including the fact that it stimulates gastric motility and intestinal functions (i.e. laxative properties). Magnesium is a relaxant, as is iron, for the nervous system and the blood vessels. Thus, it appears to be capable of fighting stress, irritability and high blood pressure. Since the present study shows that maize is lower in Magnesium, then *Moringa* can be explored as a cheaper supplement for enhance the deficiencies in Magnesium (Hill, 2008, Dhakar *et al.*, 2011b).

Table 5.6 shows that Potassium content for MOLP was higher content than that of the maize meal which had a significant difference in the Potassium content of MOLP and Maize meal.

It is noteworthy that Potassium in human nutrition is identified as a major mineral that is responsible for muscle, nerve and brain functions. Furthermore, Potassium controls and lowers blood pressure and it acts in competition with sodium. However, Potassium does work with sodium to maintain the water balance in the human system and it also assists in the regulation of the acid-base balance and water balance in the blood, which is very important for good health. Potassium also helps in protein synthesis from amino acids and in carbohydrate metabolism (Hopkins, 2017).

The mean values in Table 5.6. Show the sodium content in maize as 0.00 ± 0.00 and 0.04 ± 0.00 in MOLP. There was no sodium in the Maize meal, however, there is a significant amount of sodium in MOLP. This implies that the maize meal was lacking in sodium, thus both food materials are a good blend for the preparation of a nutritious beverage. Therefore, for those people that consume *mahewu* as a filling food, they can still derive their sodium needs when it is consumed along with MOLP.

K/ca + Mg content in maize was found to be higher, with a mean value of 0.86 ± 0.11 , than that of MOLP which was 0.19 ± 0.00 . K/ca+ Mg in food analysis refers to the concentration of Potassium, calcium and Magnesium within a food. However, Table 5.6 shows a significant difference ($P < 0.05$) between Maize and meal and MOLP content of K/ca + Mg. Literature, support that there is global evidence that three micronutrient deficiencies are of public health concern amongst children and young women (Muthayya *et al.*, 2013b). The analysis of this result suggest that *Moringa* can be adopted as a food supplement to enhance the k/ca+ Mg of the local Maize based diet.

Table 5.6 reveals that Zinc content in Maize was lower than the zinc content in MOLP which was noted higher. It is reported in the literature that *Moringa* is a good source of zinc (Dhakar *et al.*, 2011b). Another study in the literature affirms that *Moringa* leaves, pods and seeds contain zinc in amounts that are similar to the amount found in beans and it also noted that the leaf powder contains twice the amount of zinc in the quantity of beans equal to the quantity of powder. Zinc has been reported to function in supporting normal growth and development during pregnancy, childhood and adolescence periods, and also it is good for promoting a healthy immune system and the healing of wounds (Hopkins, 2017, Isitua *et al.*, 2015). Thus, MOLP could be explored for its appreciable zinc content.

Table 5.6 shows that a higher content of copper in *Moringa Oleifera* than in Maize meal, however, the content of *Moringa* was found to be lower than in the study conducted by (Moyo *et al.*, 2011). Copper majorly helps in the synthesis and maintenance of myelin, which is a fatty forming substance that insulates nerve cells and ensures the suitable transmission of nerve impulses, processes that neutralize the dangerous free radicals that would then destroy human cells. Copper and supporting enzymes give humans the capacity to produce energy for active healthy muscles, including the heart muscles. Copper enhances the appearance of the human skin and assists in the formation of bones (Hopkins, 2017).

Table 5.6 shows that manganese content of MOLP was higher than that of maize meal. It has been reported that manganese is mostly more in the bones, liver, pancreas and brain. A study in the literature affirms that manganese constitutes several enzymes such as manganese superoxide dismutase, which helps to prevent tissues from damage which is known to be caused by oxidation. Manganese stimulates numerous enzymes that are responsible for the digestion and utilization of foods, and it is notable in the breakdown of cholesterol, production of sex hormone and the functioning of bones and skin (Hopkins, 2017).

Table 5.6, iron content of maize meal was found to be high MOLP compared to maize meal. Since the mineral content in the present study was appreciable, this suggests that one of the highest nutrients in MOLP is iron. It therefore explains that *Moringa* is a good source of iron and it can be recommended for pregnant women, and the malnourished and anemic individuals of the population. Iron is one of the trace minerals which are usually found in adequate amounts in a balanced diet. In the literature, *mahewu* is noted for insufficient micronutrients, of which iron is included (Awobusuyi *et al.*, 2015b). Furthermore, it is also reported that the most dominant minerals in fortificants or supplements that are used in various food preparations are usually iron, calcium, zinc and iodine and some of the global contemporary deficiency health challenges are dominated by deficiencies of these minerals in diets (Tsegay *et al.*, 2014).

The aforementioned deficiency of iron and other micronutrient deficiencies among the sub-Saharan African countries, including South Africa, present health deficiency challenges which appear to be common among women within their productive age and young children - especially with ages of 0-5 years (Tulchinsky, 2010, De-Regil *et al.*, 2013). Thus, the present study confirms a high iron content in MOLP than in Maize meal and if micronutrient malnutrition especially iron deficiency- challenges must be addressed, then a conscious effort must be made to ensure that maize or other cereal-based food products are supplemented by the supplies of an adequate quantity of iron. Interestingly, many leafy edible plants are identified as rich in iron, especially dark green leafy vegetables such as *Moringa Oleifera* (Phaswana-Mafuya and Peltzer, 2015)

5.3.4 Macronutrient composition of supplemented *mahewu*

Table 5.7 shows significant differences in the findings, with a high mean value with different superscript letter across each row and a statistical significant value of $p < 0.05$. The result reveals the proximate composition of MOLP-supplemented *mahewu* beverage in which there is an

increase in the degree of MOLP in the *mahewu*. Decrease in moisture content was noted, specifically on the 2% and 4% prototypes, compared to the control sample, and the decrease was reflected across the mean values ranging from 0% $.53 \pm 0.65$, 2% 2.07 ± 0.15 , 4% 2.15 ± 0.03 and 6% 5.02 ± 1.56 , respectively. There was a significant difference in the value of $P < 0.05$. The lowest value was observed when 2% *Moringa Oleifera* leaf (MOLP) powder was added. The highest value of moisture was noted when 6% MOLP was added to the *mahewu* beverage. This implies that, addition of MOLP decreases moisture content and increases the density of the chemical food nutrients. Thus, since it has been established that MOLP contains lots of vitamins and minerals, then it is a potent supplement for enhancing nutrient inadequacies in cereals food products, and especially maize-based beverages.

Ash The ash content in 0% *mahewu* beverage was 1.66 ± 0.17 with respect to the reference sample and the values were: 2% 2.14 ± 0.59 , 4% 2.02 ± 0.04 and 6% 2.27 ± 0.06 , respectively. The Ash content of all the MOLP-supplemented *mahewu* was increasing with the addition of MOLP in various degrees. Six percent (6%) had the highest value. This value of Ash indicates that the leaf is rich in other minerals and elements which could be very high in content. Therefore, one conclusion that could be made is that, as the percentage of *Moringa Oleifera* was increasing in percentage, the quality of *mahewu* mineral content was also being enhanced. Although there is no (or limited) documentation on the addition of *Moringa* in *mahewu*; this investigation can be supported by the study conducted by Oyeyinka (Oyeyinka and Oyeyinka, 2016, Sengev *et al.*, 2013). Who added *Moringa* powder in other starchy food products such as *Amala*, which is a stiff dough Nigerian food, and also in *ogi* which is a maize-based beverage, which reported an increase in nutritional value (Sengev *et al.*, 2013).

Fat The fat profile of the *Moringa Oleifera* leaf powder (MOLP) content was recorded as $.87 \pm 0.17$ for the control, 2% 3.02 ± 0.08 , 4 % 3.18 ± 0.06 , and 6% 2.27 ± 0.06 . It has been argued that MOLP is a good source of mono-saturated, poly-saturated and trans fatty acids (Isitua *et al.*, 2015). The 6% supplemented *mahewu*, recorded the highest fat content and the reference *mahewu* sample recorded the lowest fat which implies that *Moringa* can enhance the fat content of foods that have less content of healthy fat. The study explains that the nutritional values of the sample were appreciable, especially with respect to healthy fat content which plays a vital role in the absorption of fat soluble vitamins, providing energy and the cushioning of delicate organs.

Furthermore, monounsaturated fats are reported to reduce cholesterol level, and to decrease the risk of stroke and heart disease (Garba *et al.*, 2015).

Acid detergent fiber (ADF) profile was within the range 0% 8.45 ± 0.28 , 2%, 7.20 ± 1.12 , 4% 6.95 ± 0.28 , and 6%, 7.44 ± 0.78 and Neutral detergent fiber (NDF) profile was within the range 0% 11.70 ± 0.36 , 2% 11.22 ± 0.36 , 4% 11.47 ± 0.08 and 6%, 12.03 ± 0.74 . The result showed an appreciable fiber content.

Dietary fibers constitute substances that are not digested by gastrointestinal enzymes but still play vital role in human and animal nutrition. Fiber has been considered as a cleanser in the digestive tract by removing potential carcinogens from the body. Therefore, the presence of fiber in any diet is regarded as essential because it provides roughages for the regularity of the bowels, thereby assisting intestinal transportation. A high fiber diet is known to be important in preventing the absorption of excess cholesterol and also in normalizing blood lipids, thereby reducing cardiovascular disease and increasing the prevention of constipation and diverticulosis inflammation. Fiber assists in maintaining an optimal pH in the intestines; insoluble fiber help stop microbes from producing substances which can lead to colorectal cancer. However, it is reported that very low fiber in food is, however, helpful in digestive processes even though it lowers the vitamins and enzyme content of the food material. It is reported that fiber is good for the health because it also has cholesterol lowering benefits (Mgbemena and Obodo, 2016). The crude protein profile was recorded as 0% 8.92 ± 0.11 , 2% 9.16 ± 0.28 , 4% 9.90 ± 0.05 and 6% 9.89 ± 0.16 . Compared to the reference sample, this result indicates that following the addition of the MOLP in varying degree of 2%, the protein content is being increased in an appreciable manner. Thus, it is confirmed that *Moringa* can enhance the protein content of foods that are low in protein content. According to Mgbemena (2016), the 20 comprising essential amino acids and the nonessential amino acids are seen in MOLP. Proteins are recognized as polymers of amino acids. Protein acts as enzymes, hormones and antibodies (Mgbemena and Obodo, 2016). *Moringa leaf powder* can, hence, be considered as a complete food since it contains all the essential amino acids required for a healthy body. The findings confirm that MOLP is a good source of important nutrients and thus the plant can be explored as a viable whole food supplement for malnutrition challenges in both animal and human nutrition.

5.3.5 Micronutrient composition of the supplemented *mahewu*

Table 5.8 reveals the mineral composition of MOLP-supplemented beverage (0% 2%, 4%, and 6%).

Calcium content in Table 5.8, is in the range of 0.02 ± 0.00 , 0.09 ± 0.01 , 0.16 ± 0.00 and 0.21 ± 0.00 . An increase in calcium content level was noted, with the increasing value of percentage (2%, 4% and 6%) of MOLP in *Mahewu* beverage. A high mean value was noted across all the prototypes compared to the control (reference sample); a 2% sample had the lowest mean value and a 6% sample had the highest mean value. This suggests that an increase in the percentage of MOLP enhances the mineral content of the *mahewu*.

Magnesium content in Table 5.8 is in the range of 0.11 ± 0.00 , 0.12 ± 0.00 and 0.13 ± 0.01 and in 0.14 ± 0.00 . With the increase in percentage of *Moringa Oleifera* leaf powder (MOLP), an increase in the magnesium content was noticed which implies that MOLP is a rich source of magnesium. Magnesium appears to be vital to health because it sensitizes the gastric contraction of muscle and intestinal function, it is a laxative that has relaxing iron for the nervous system and blood vessels, thus it combats stress, irritability and high blood pressure (Hopkins, 2017). Potassium content in Table 5.8 is in the range of 0.35 ± 0.03 , 0.38 ± 0.01 , 0.41 ± 0.01 and 0.41 ± 0.00 . MOLP is a good dietary source of magnesium for human nutrition. Table 5.8 shows that sodium content in this study was low and in the range of 0.01 ± 0.00 , 0.01 ± 0.00 , 0.01 ± 0.00 and 0.01 ± 0.00 there was no sodium in the proximate analysis of maize meal that was used for the sample, but MOLP has a low content of sodium. Thus, the low content of sodium across the prototypes is associated with the increasing percentage of MOLP. Therefore, the addition of MOLP has little effect on the sodium content of white maize *mahewu* beverage. Sodium is one of the principal cautions in extracellular fluids, which is involved in the regulation of plasma volume and acid-base balance (Mbailao *et al.*, 2014). Therefore, it can be concluded that *Moringa*-supplemented *mahewu* beverage is low in sodium hence a high blood pressure patient can consume, and derive nutritional benefits from, MOLP-based food products. The zinc content in Table 5.8 is in the range of 28.50 ± 3.54 , 27.00 ± 0.014 , and 25.00 ± 0.00 and 25.00 ± 0.00 . This study reveals an increase in the zinc content of the supplemented *mahewu*. Therefore the study suggest that *Moringa* can be a source of Zinc, and can be explored to enhance foods that are lacking in zinc content. A healthy immune system requires zinc which has been identified to support a healthy immune system, for normal growth and development. Zinc as well has the

ability to help women to recover from injuries incurred in the course of pregnancy and delivery, as well as wounds that was gotten during childhood and adolescence stages. It has been mentioned that everything about *Moringa* is exceptional in the sense that the leaves of *Moringa*, pods and seeds contain zinc in amounts that are alike with those obtained in beans, also in the aforementioned review dry *Moringa* is dense with vitamins and minerals thus the leaf powder MOLP contains twice as much zinc per the same weight (Hopkins, 2017).

Copper content in Table 5.8 is in the range of 2.50 ± 0.71 , 3.50 ± 0.71 , 3.50 ± 0.71 and 4.00 ± 0.00 . There was an increase noted with increasing *Moringa* leaf powder. Thus, it can be explored for copper content in foods that are deficient in their content of Copper. Copper is noted to play a good role in enhancing skin appearance and is a component in bone formation including synthesizing and maintaining myelin, which is a substance that protects nerve cells, ensuring the proper transmission of nerve impulses. It is also a co-factor that helps in neutralizing the dangerous free radicals that would otherwise destroy human cell (Mbailao *et al.*, 2014, Hopkins, 2017). Manganese content is in the range of 7.00 ± 0.00 , 9.00 ± 0.00 , and 9.50 ± 2.12 -and 10.50 ± 0.00 , hence, there was an appreciable content of manganese. It is argued that *Moringa* is a potential plant for human consumption with varied nutrients and perhaps some of those nutrients are yet to be discovered, thus MOLP could be used to enhance foods that are lacking in manganese.

Iron content in Table 5.8, reveals the highest-content element and the result is in the range of 26.00 ± 2.83 , 53.50 ± 0.71 , and 81.50 ± 4.95 and 100.50 ± 9.19 . The present study confirms what has already been discussed in the literature in several of the aforementioned studies that reported *Moringa* to be an excellent plant for iron supply in human and animal nutrition. It noteworthy that it contains an appreciable content of iron and more so than in spinach. Iron is a component of hemoglobin, the oxygen that is a carrier. Magnesium is a component in many metabolism systems. Thus, *Moringa* can be utilized to address anemic health challenges.

Besides energy and protein malnutrition, vitamin and mineral deficiency (hidden hunger) has been discussed in the literature as the most concerning health problem (Tsegay *et al.*, 2014). Micronutrients should be a key point of consideration when preparing food because a dietary requirement for micronutrients is being defined as an intake level which meets some specified criteria of adequacy, thereby reducing the risk of a deficiency in nutrient or excesses of it (Hopkins, 2017). Thus, this study suggests that MOLP has hidden potentials that need to be address, such as vitamin and mineral deficiency issues. The present study confirms that the

increased MOLP in the percentages of (2%, 4% and 6%) in fermented porridge can appreciably enrich the nutrient content of *mahewu* and especially the essential mineral and protein content which is known to be low in maize-based food products. Therefore, it could be recommended in mineral-deficient communities to enhance the maize-based food products that are lacking (or insufficient) in mineral content.

5.3.6 Overview of consumer acceptability of MOLP-supplemented *mahewu*

Sensory evolution and consumer acceptability of farm-grown maize *Moringa Oleifera* (MOLP)-supplemented *mahewu* beverage was conducted at the study site.

Figure 5.2 shows a panel graph which reveals the result of the sensory attributes and the consumer acceptability of MOLP-supplemented *mahewu* (0%, 2%, 4% and 6%).

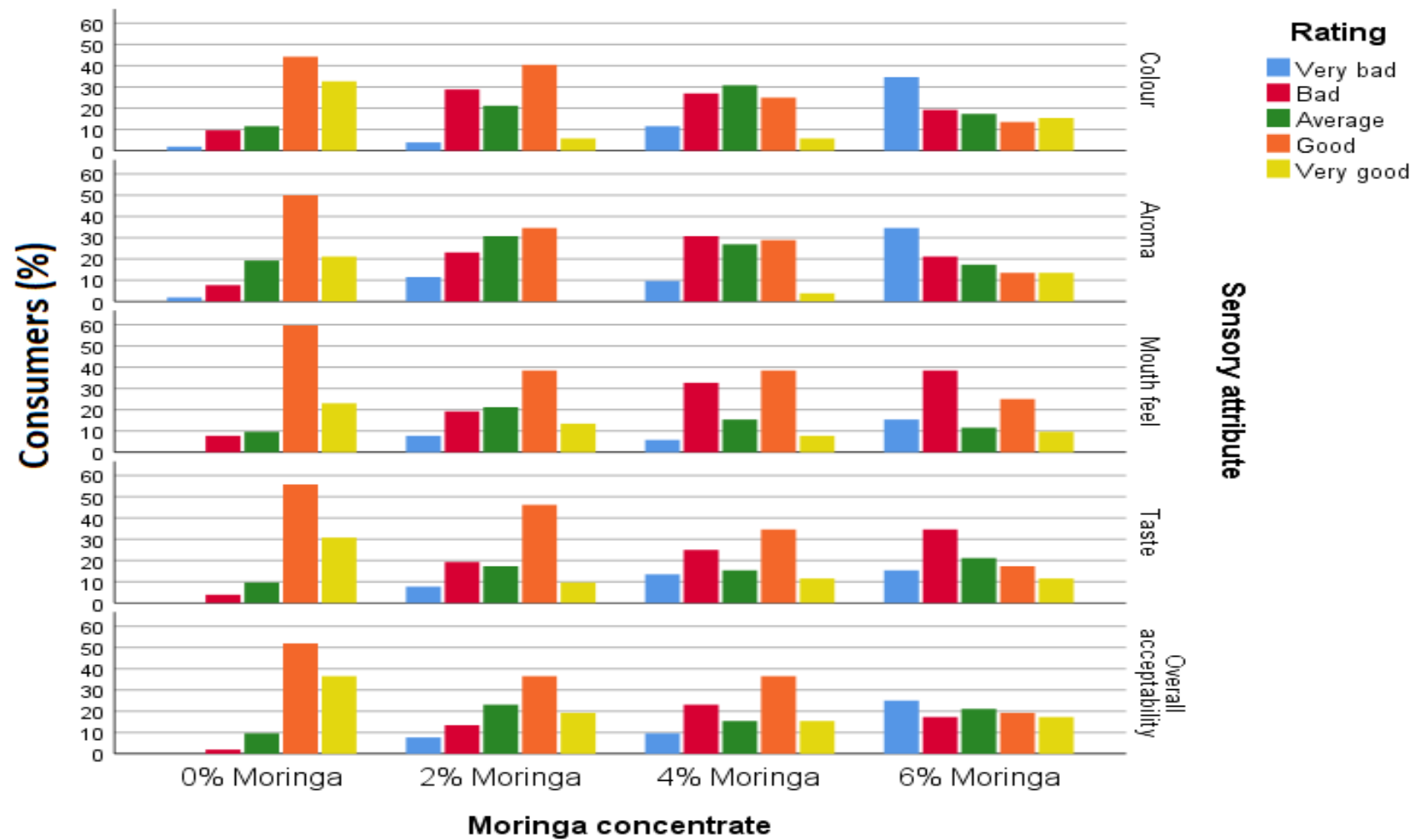


Figure 5. 2: An overview of the sensory evaluation of MOLP-supplemented mahewu beverage

5.3.6.1 Color sensory acceptability of the four prototypes of mahewu samples

Figure 5.2 reveals a high proportion of the panelists (46, 88%) accepting the color of the 0% MOLP sample, only 6 (12%) disliked the color, and perhaps if the maize was shelled the color would have been enhanced like that of the commercial *mahewu*. Also, a significant proportion (35, 67%) of panelists accepted the 2% MOLP sample, and only 17 (32%) disliked the color. A number of panelists (32, 61%) liked the color of the 4% MOLP sample, while only 20 (38%) disliked the sample. A significant proportion of the panelists (24, 46%) disliked the color of 6% MOLP sample. Generally, with respect to the color, the acceptability of the 2%, and 4% samples was high and similar to the control sample.

5.3.6.2 Consumer's aroma sensory acceptability of the four prototypes of mahewu samples

Figure 5.2 reveals that a high proportion of the panellist's (41, 91%) accepted the aroma of the 0% MOLP sample, only 5 (10%) disliked the aroma, and perhaps if the maize was shelled the aroma might be like that of the commercial *mahewu*; only a few panellist's (10%) disliked the color which could be due to the method of preparation. A significant proportion (34, 65%) of panellist's accepted the 2% MOLP sample and only 18 (34%) disliked the aroma. Quite a large number (31, 60%) of panellist's liked the aroma of the 4% MOLP sample, while only 20 (40%), and disliked the aroma of the 4% MOLP sample. However, a significant proportion (29, 56%) of the panellist's disliked the aroma of the 6% MOLP sample while only 3 (44%) liked it. Relatively, with respect to the aroma, the acceptability of 2%, and 4% sample was high and similar to the control sample, respectively.

5.3.6.1 Consumer mouthfeel sensory acceptability of the four prototypes of mahewu samples

Figure 5.2 reveals that a high proportion of the panelists (48, 92%) appreciated the mouthfeel of the 0% MOLP sample, only 4 (9%) disliked the mouth feel. Also, a significant proportion of panelists (38, 73%) appreciated the 2% MOLP sample and only 14(26.9%) disliked the mouthfeel. Quite a number of panelists (14, 62%) appreciated the mouthfeel of the % MOLP sample, while only 20 (39%) disliked the mouth feel of the 4% MOLP sample. However, a significant proportion of the panelists (28, 54%) liked the aroma of the 6% MOLP sample only 24 (46%) disliked the sample. Relatively, with respect to the mouthfeel, the acceptability of the 2%, 4% and 6% samples was high and similar to the control sample.

5.3.6.2 Consumer taste sensory acceptability of the four prototypes of mahewu samples

Taste is an important sensory attribute in sensory evaluation of any food products. The results in Figure 5.2 reveal that a high proportion of the panelists (50, 96%) appreciated the taste of the 0% MOLP sample, only 2 (4%) disliked the taste. Also, a significant proportion of panelists (38, 73%) appreciated the 2% MOLP sample and only 14(27%) disliked the taste. Quite a number of panelists (14, 62%) appreciated the taste of the 4%MOLP sample, while only 20 (39%), and disliked the mouthfeel of the 4% MOLP sample. However, a significant proportion of the panelists (26, 50%) disliked the taste of the 6% MOLP sample, while only 26 (50%) liked the sample. Relatively, with respect to the taste, the acceptability of 2%, 4% and 6% samples was high and similar to the control sample.

5.4 Conclusion

The findings reveal that the proximate and the individual mineral profile of MOLP were higher in composition compared to the profile of maize meal, thus, the raw materials are a good blend for developing a nutritious beverage that is even acceptable for children. Likewise, the nutritional analysis of the supplemented *mahewu* reveals that MOLP is able to enhance the nutritional composition of the conventional *mahewu* at 2%, 4%, and 6%, with special reference to the Fat fibre and protein, which satisfy the macronutrient needs of humans and animals. Although ash was also high, in Table 5.7 there is an enrichment of the overall mineral content of the supplemented beverage notably, with a high content of Calcium, iron, copper, magnesium, potassium, and other minerals that were detailed in section 5.3.3. This study confirms that with increased percentage of the MOLP in the three samples, the nutritional value was increasing progressively and especially with respect to the macronutrients: Fat, fiber and protein and the micronutrients: iron, copper, calcium and manganese. Thus, a consistent intake of 2% MOLP in the diet might be appreciable in boosting the immunity and for preventing malnutrition, whereas, 4% and 6% might be explored for addressing the pre-existing or acute malnutrition problems, especially micronutrient deficiency challenges. Since iron and calcium are high in the supplemented *mahewu* beverage; then it implies that MOLP can be explored as a food supplement for tackling the escalating levels of iron deficiency challenges among the disadvantaged population. Especially with respect to women of productive age (lactating and pregnant including adolescent girls) and people who had suffered a long illness and perhaps have become anemic.

The high protein content of MOLP can be explored for the prevention, and addressing, of Protein and energy malnutrition (PEM) in communities who are PEM challenged.

The supplementation of MOLP in *mahewu* improves the nutritional composition of the *mahewu* in terms of total mineral content, fat fiber and protein and ash composition, as aforementioned. Likewise, the individual mineral content also increased progressively and notably the Calcium, copper, and iron and manganese. Furthermore, *mahewu* beverage was enhanced nutritionally, with the increasing percentage of the MOLP. The overall acceptability reveals that the color, aroma, mouthfeel, taste, and the overall acceptability of MOLP-supplemented *mahewu* were relatively high and similar. A very low proportion of the panelists disliked any of the sensory attributes of the MOLP-supplemented *mahewu* beverage. This study reveals a relatively high proportion of panelists (46%) who disliked the color and mouthfeel sensory attributes of the 6% MOLP-supplemented *mahewu* beverage. Likewise, there was a significant proportion of panelists (56%) who disliked the aroma of the 6% MOLP *mahewu* beverage. It was assumed that the taste would be disliked, however, 50 panelists liked the taste and another 50 panelists disliked the taste. The findings of this study show that, generally, the sensory properties of MOLP-supplemented *mahewu* beverage were similar, however, the 6% MOLP sample can be improved through the masking of the color, aroma and perhaps the taste for better consumer sensory attributes.

5.4.1.1 Overall consumer sensory acceptability of four prototypes of mahewu samples

Although with the increase concentration of MOLP the overall consumer sensory attributes were decreasing, the color, aroma, mouthfeel, taste, and the overall acceptability of MOLP-supplemented *mahewu* were relatively high and similar. A very low proportion of the panelists disliked any of the sensory attributes of the MOLP-supplemented *mahewu* beverage. This study reveals a relatively high proportion (46%) of panelists who disliked the color and mouthfeel sensory attributes of the 6% MOLP-supplemented *mahewu* beverage.

Similarly, there was a significant proportion of the panelists (56%) who disliked the taste of the 6% MOLP *mahewu* beverage. It was assumed that the taste of the supplemented *mahewu* beverage will be disliked, however, 50% of the panelists make up those who rate average, good and very good which show some levels of acceptance of the 6% MOLP sample and likewise with the 50% of panelists who disliked the taste of the 6% supplemented sample. The findings of this study show that, generally, the sensory properties of MOLP-supplemented *mahewu* beverage were similar. However, the 6% MOLP sample can be improved through masking of the color, aroma and taste for better consumer sensory attributes and consumer acceptance.

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CHAPTER SIX

CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH

6.1 Introduction

Adequate nutrition is widely recognized as an essential element for a healthy and productive lifestyle. However, worldwide studies declare an estimate of two million people who are challenged with diseases via deficiencies of essential vitamins and minerals (micronutrient), commonly known as hidden hunger. It is termed hidden hunger because those who are affected by the consequences of these deficiencies do not manifest the physical symptoms that are commonly associated with hunger and malnutrition - hence, that hunger is masked or hidden. Studies in the literature report that twenty countries are experiencing an alarming degree of micronutrient deficiencies, and eighteen are from sub-Saharan Africa while the other two are in Asia. Iron deficiency anemia, stunting, and vitamin A deficiency (VAD) are highly ascribed to preschool aged children in countries with the highest prevalence. Aside for any other factors, the leading cause of these challenges is mostly nutrient-deficiency related and such challenges are preventable. The bulk of the deficiencies are ingestion of inadequate foods, over-reliance on starch-based staple foods, which become monotonous with no bioavailable food sources.

Mahewu is a common southern African beverage, which provides most of its consumers with energy, poor quality protein and insufficient vitamins and minerals. On the other hand, adequate nutrition is recognized as a major key role for wellbeing. *Moringa Oleifera* has an origin that is traced to the sub-Himalayan areas of India, Pakistan, Bangladesh, and Afghanistan, but now it is gaining more recognition worldwide - and in sub-Saharan Africa including southern Africa. *Moringa Oleifera* has been identified as a multipurpose plant and its popularity is obviously for its industrial and medicinal purposes because it is identified as being loaded with phytochemicals, and is high in nutritional value, and beneficial to human and animal wellbeing. It is a nontoxic food plant and it has been utilized as fortificants and supplements in diverse food developments, especially the foods that are low in essential nutrients. Although the *Moringa Oleifera* plantation project is ongoing in the study area, this study reveals that considerable proportions of the population in Ntambanana are unaware of the economic values, and the nutritional and multipurpose hidden benefits of *Moringa Oleifera*. This study investigated the nutritional composition and acceptability of *Moringa oleifera* leaf powder (MOLP)-supplemented *mahewu* that is a maize meal-based beverage that is destined for improved food and nutrition security in Ntambanana in the KwaZulu-Natal province of South Africa. In the course of this study, the utilization of *mahewu* alongside with the rural household perceptions of *Moringa* in Ntambanana were assessed. The indigenous practices of

processing of *mahewu* beverage in KwaZulu-Natal province of South Africa were documented. The literature confirms that the low consumer acceptability of MOLP food products, has been associated with the impacts of MOLP on the sensory attributes of MOLP food products. *Moringa* leaf powder has been added to a maize gruel called *ogi* which is a Nigerian beverage and also with other food products across Sub-Saharan Africa, however, this is not the case with *mahewu*. Hence, there is no, or limited, information concerning where *Moringa* leaf powder has been added to *mahewu*. Therefore, both raw materials (Maize meal and MOLP) were analyzed for their nutritional composition. Also, the effects of MOLP on the nutritional composition of (0% 2%, 4% and 6%) MOLP-supplemented *mahewu* beverage were investigated including the consumer acceptability of (0% 2%, 4% and 6%) MOLP *mahewu* beverage - all were assessed in the study area.

The findings of this study affirm that *mahewu* is a common fermented cereal beverage which can be made from other cereals (sorghum millet), but predominantly white maize is used in the Ntambanana rural community. *Mahewu* is one of the most common indigenous beverages that is consumed as a refreshing drink in local ceremonies, after a hectic day and to some it is consumed as a filling-food which is consumed by all groups of all ages, including infants as a weaning food and also as a food for the growing children. The survey of this study indicates that 95.7% of the rural households of Ntambanana consume *mahewu* as a common beverage at any time in all seasons, although with a higher frequency in the summer months. Considering the food and nutrition security of those who consume *mahewu* as a food, nutritional analysis of the conventional *mahewu* and consumer acceptability of the supplemented *mahewu* samples were assessed. This study indicates that with an increased concentration of MOLP in the *mahewu*, a significant difference ($p < 0.05$.) was observed, especially in relation to the macronutrient fat, fiber and crude protein. Also, the individual minerals such as calcium, iron, copper, manganese potassium and magnesium were enhanced significantly ($p < 0.05$.) Therefore, the increase of MOLP in staple-based food products is able to enhance their nutritional composition and macronutrients, and especially the micronutrients. The nutritional analysis preceded the sensory evaluation of the supplemented samples for the study.

The findings reveal that 2% and 4% prototypes were appreciated as the control sample (0% MOLP). The color and aroma of the 6% prototype were not accepted, however, the taste was relatively appreciated. The control sample with a lesser nutrient profile had the highest overall acceptability. Furthermore, the standard nutritional analysis confirms that *Moringa* is very rich in crude protein, fat, and fiber, high in individual mineral content especially with respect to

calcium, copper, iron, manganese and potassium which were high among the other nutrients that were recorded in this study.

Conclusively, this study reveals that dried leafy powdered of *Moringa Oleifera* (MOLP) can be explored to enhance the nutritional value of staple-based food products, and it could be used in foods that are low in protein and micronutrients, including the trace minerals - especially for pregnant lactating, elderly and individuals suffering from HIV, AIDS and Non-communicable diseases. Thus, *Moringa* can be recommended for malnourished vulnerable groups, especially for those who consume *mahewu* as a filling food, including infant and children. However, this study suggests that a better technique may be explored to mask the (color, aroma and the taste) of 6 % MOLP-supplemented *mahewu* beverage.

6.2 Recommendations

A practical approach concerning malnutrition requires demand and supply as well as strong political commitment to help in disseminating information about foods that are dense in the proper nutrients. This will aid in achieving the goal of food and nutrition security. The *Moringa* plantation thrives at Luwamba buchana Ntambanana. Thus, a continuous investigation on the correct and proven interventions, which are self-reliant for population that is vulnerable to malnutrition, this is to ensure more availability and other *Moringa* plantations as essential tools to combat the problems outlined in this research. This must eventually lead to awareness and the utilization of *Moringa* vegetables in other indigenous diets.

Moringa has more nutrients that are yet to be discovered and more studies should be carried out to unveil these nutrients. There is, therefore, the need to popularize the plant among the people (both the literate and the illiterate) through various sensitization and enlightenment media programs, such as electronic and print media, seminars and workshops and many other such tools are needed to create more awareness to enhance *Moringa* utilization in staple foods.

6.3 Future Research

In this study, *Moringa Oleifera* had higher nutritional value compared to the nutrient composition of maize. *Moringa Oleifera* leaf powder (MOLP) showed great effects on the proximate and the individual mineral nutritional composition of all the MOLP-supplemented *mahewu* prototypes. This study reveals that MOLP-supplemented *mahewu* beverage can provide the consumers with essential amino acids and essential micronutrient (essential vitamins and minerals). However, MOLP-supplemented *mahewu* is not commonly known in South Africa. Thus, further investigation in developing MOLP-supplemented beverages as a

nutrient-dense beverage for food and nutrition security is essential. It is established that most plant-based foods contain some amount of anti-nutritional compound such as phenolic compounds which include phytates, saponins, and tannin. It is also noted that the bitter taste is linked with the tannin content in foods. *Moringa* is a plant food that has been known to contain some concentration of tannin which was not measured in this study. Perhaps, the levels of the tannin might be significant and might be responsible for bitter taste reported. Low consumer acceptability level of the supplemented beverage was evident in 6% prototype. Therefore, to enhance the MOLP supplemented *mahewu* desirability and acceptability level, further studies can investigate on the tannin content of 6% prototype, also further study may necessitate the addition of artificial flavorings and colorings in to the supplemented *mahewu* beverage.

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LIST OF APPENDICES

Appendix A: Pictures of Home-grown *Moringa Oleifera* in KwaZulu-Natal, South Africa



Appendix B: Manual grinding device for grinding maize

(An improved-technology device for grinding maize)



Appendix: C - Preparation of mahewu in the food laboratory



Maize ready for paste



Making a paste with Maize meal and cold water



Making of slurry porridge in progress



Maize porridge added waiting to cool to a tepid temperature



Porridge with added sugar still undergoing cooling process before fermentation



Fermentation of porridge in progress



Four prototypes of *Moringa Oleifera* supplemented *mahewu* beverage (0%, 2%, 4% and 6%)



Samples in a freeze dryer

Appendix D. Sensory evaluation of Moringa Oleifera-supplemented mahewu beverage:

Appendix D Recipe for the reference *mahewu* sample and the MOLP-supplemented *mahewu* beverage.

The *mahewu* beverage was developed based on the quantity of *mahewu* that was sufficient for the 60 panelists for the sensory evaluation. A total of 16 L was prepared for the four prototypes (AA 0%, AB 2%, AC 4%, and AD 6%). The recipe for the aforementioned was developed after a series of trials in the food laboratory, University of KwaZulu-Natal, Pietermarisburg Campus, where a substitution method was explored. The recipe is detailed in Appendix F, the method of preparation for the 4 L for each sample used for the sensory evaluation is detailed in Appendices G to I.

Appendix E: Substitution of MOLP for Maize Meal for the 4 Samples for nutritional analysis and the Sensory Evaluation

The substitution method was adopted for the recipe of 4 L of *mahewu* beverage for the sensory evaluation. The recipe was developed under the same conditions as for the sample for nutritional evaluation in section 3.11.

Sample 1. The first sample being the control sample 0% MOLP.

Sample 2. $480 \times \frac{2}{100} = 9.6$ then $480 - 9.6 = 470$ g of maize.

The 2% MOLP ratio (9.6 g of *Moringa*) was substituted for white maize meal, thereby reducing the gram weight for maize meal and replacing it with the equivalent ratio of MOLP. Thus, 470

g of maize meal with 9.6 MOLP and 5000 mL of water was used to have a yield of 4 L of *mahewu* beverage, as seen in Table 2.6.

Sample 3. $470 \times \frac{4}{100} = 18.8$ then $480 - 18.8 = 461.2$ g.

Then 461.2 g of maize was used with 18.8 g of *Moringa* thus 480 g of maize was used with 18.8 g of MOLP and 5000 mL of water to 4 L yield of *mahewu* beverage as detailed Table 2.6.

Sample 4. $480 \times \frac{6}{100} = 28.8$ then $480 - 28.8 = 451.2$.

Thus 451.2 g of maize meal was used with 28.8 g of MOLP and 5000 mL of water was used for 4 L yield of *mahewu* beverages as shown in the table below. Other recipes were developed in the same manner as the control, however, with their varying MOLP ratios.

Appendix F Summary of substitution of MOLP for maize meal for the 4 L of mahewu beverage prototypes for sensory evaluation

Samples	Maize grams	<i>Moringa</i> in grams	Water mL	Sugar grams	Total yield liters
0%	480.0	0.0	5000	200	4
2%	470.4	9.6	5000	200	4
4%	460.8	19.2	5000	200	4
6%	451.2	27.8	5000	200	4

Appendix G. Adopted standardized Recipe of Mahewu Beverage, for the Control Sample and for the Sensory Evaluation exercise

Recipe *Mahewu* recipe for one litre of *mahewu* samples for the nutritional analysis

Appendix H: Coding of Samples for Sensory Evaluation

To reduce biasness associated with the labeling of samples, a table of random numbers was assigned to each sample and a unique three-digit code, as provided in the table below. However, the codes of the samples were strictly meant for the researcher (myself) guide and not for the panelists or the research assistants.

The table below showing coding of *Moringa Oleifera*-supplemented *mahewu* beverage

Sample	<i>Moringa</i> ratio	Code
AA, control	0%	549
AB	2%	649
AC	4%	686
AD	6%	695

Through the research assistants, the beverage was being served cold to the volunteered panelist based on the serving order.

Appendix I: INFORMED CONSENT

PROJECT TITLE: - The acceptability of *Moringa oleifera*-supplemented *mahewu* beverage for the improved food and nutrition security of rural community Ntambanana in Epangeni municipality, KZN, South Africa.

RESEARCHER:

Ruth Olusanya (215081315)

Discipline of Food Security,

School of Agriculture, Earth & Environmental Sciences,

College of Agriculture, Engineering & Science,

Pietermaritzburg Campus

Proposed Qualification: Master of Agriculture (Food Security)

Contact: 0736946235/0743309971 Email: rutholusanya@hotmail.com

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Sefako Makgatho Health Science University

Gauteng. E-mail: Annette.vanonselen@smu.ac.za

I am Ruth Olusanya, a master's student with the student number 215081315. Discipline of Food Security, School of Agriculture, Earth & Environmental Sciences, University of KwaZulu Natal, Pietermaritzburg Campus.

This research is centered on food and nutrition intervention strategy in addressing micronutrient deficiencies. As part of my research, I am developing a nutritious beverage (*mahewu*) by incorporating *Moringa oleifera* powder which is obtained from a nutrient-dense food plant. I am exploring the consumer acceptance of the product and I am undertaking a study in your community.

Therefore, you are cordially invited to participate in a research project that is named above. The aim of the study will help to provide some insights on whether *Moringa mahewu* beverage will be acceptable by people. Your confidentiality is guaranteed, as your input will not be attributed to you as a person but will instead be reported only as a population member opinion and it will not be used against you personally. Your participation in this study is absolutely voluntary and there is no penalty if you do not participate. Your involvement will be used purely as part of an academic exercise. The questionnaire will take approximate 30-40 minutes to complete. Please kindly sign on the dotted line below, to show that you have read and understood the contents of this letter and also indicate your interest for this exercise.

Thank you.

DECLARATION OF CONSENT

I..... (Full Name) hereby confirm that I have read and understand the contents of this letter and the nature of the research project has been clearly explained prior to participating in this research project. I understand that I am at liberty to withdraw from the project at any time, should I desire to do so.

The ethical approval for this study was obtained from the University of KwaZulu-Natal Humanities and social science ethics committee with reference number HSS/0559/016

Appendix J: Questionnaire for sensory evaluation in Zulu language

Five point hedonic pictorial scale for sensory evaluation - Zulu language version

Inhlolovo yesiZulu yokuhlolisisa imibono yokwamukelwa kwesiphuzo *samahewu* esengezwe nge*Moringa* noma esifakwe i*Moringa*.

Igama lomphenduli: _____ Ubulili bomphenduli: ---- Iminyaka yomphenduli-----

Kekelezela okufanela: Uyasebenza noma Awusebenzi






Inombolo yesampula: _____ Usuku: _____

IMIYALELO






- Sicela uyakaze umlomo wakho ngamanzi anikeziwe ngaphambi kokuba uqale ukunambitha amasampuli, Phinda uyakaze umlomo wakho ngamanzi emva kokunambitha isampula ngayinye.
- Nambithisa amasampuli esiphuzo *samahewu* ngedlela abekwe ngayo kusukela kwesobunxele kuya kwesokudla.
- Hlola isiphuzo esiphambi kwakho. Shono ukuthi ucabangani ngendlela esinambitheka ngayo, iphunga, umbala, indlela esizwakala ngayo emlonyeni kanye nendlela osithanda ngayo nje. Khombisa lokhu ngokubeka uphawu [X] eduze kobuso obuqondene nomuzwa wakho.
- Yakaza umlomo wakho ngamanzi emva kwesiphuzo ngasinye. Ungayakaza futhi nanoma ngasiphi isikhathi ngenkathi uhlola lokudla.
- Uma unomubuzo ungabuza.

- Maka ubuso obubodwa ngo [X] okuvumelana nesinqumo sakho ngezihlokwana ezibhaliwe




1. Umbala

				
Kubi kakhulu	Kubi	Mhlawumpe Kubi noma mhlawumpe kumanandi	Kumnandi	Kumnandi kakhulu



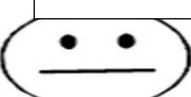


2. Iphunga

				
Kubi kukhulu	Kubi	Mhlawumpe kubi noma whlawumpe kumanandi	kumnandi	kumnandi kakhulu

3. UKuzwana ng

				
Kubi kakhulu	Libi	Mhlawumpe kubi noma whlawumpe	kumnandi	kumnandi kakhulu

4. UKUnambitheka

				
Kubi kakhulu	Kubi	Mhlawumpe kubi noma whlawumpe	Kumnandi	Kumnandi kakhulu

5. ISINQUMO JIKELELE

				
Kubi kakhulu	Kubi	Mhlawumpe kubi noma whlawumpe	Kumnandi	Kumnandi kakhulu

NGIBONAKAKHULU!!!!

Appendix: K – Questionnaire for sensory evaluation in English Language

English Questionnaire for the sensory evaluation of consumer acceptability of *Moringa Oleifera*-supplemented *mahewu* beverage

Name of respondent: _____ Gender-----Age-----






Panelist serial number-----Sample number-----

Date: _____






Instructions:

Please rinse your mouth with the water that is provided before you start tasting the samples. Also, rinse your mouth with the same water after your tasting of each sample. Kindly taste *mahewu* in the order presented from left to right. Please using the writing materials provided, and you are to rate the color, aroma, mouthfeel, taste and the overall acceptability of the samples by marking an X on the face that you think best describe the samples, and you may re-taste the sample if you wish to do so. Thank you

1. Color

				
Very bad	Bad	Average	Good	Very good






2. Aroma

				
Very bad	Bad	Average	Good	Very good






3. Mouthfeel

				
Very bad	Bad	Average	Good	Very good

4. Taste

				
Very bad	Bad	Average	Good	Very good

5. Overall Acceptability

				
Very bad	Bad	Average	Good	Very good

THANK YOU

Appendix L – Ethical Clearance approval



23 September 2016

Mrs Ruth Olusanya (215081315)
School of Agricultural, Earth & Environmental Sciences
Pietermaritzburg Campus

Dear Mrs Olusanya,

Protocol reference number: HSS/0559/016M

Project title: The acceptability of Moringa Mahewu white maize based beverage for the improved food and nutrition security of rural household Ntambanana

Full Approval – Expedited Application

In response to your application received on 11 May 2016, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Dr Shenuka Singh (Chair)

/ms

Cc Supervisor: Dr Annette van Onselen and Dr Unathi Kolanisi
Cc Academic Leader Research: Professor O Mutanga
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee

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Westville

Appendix: M – Questionnaire for survey

Questionnaire for Survey (Utilization of *Mahewu* and *Moringa Oleifera*)



Section A: Socio-Demographic Information

1.

1.	Male		
2.	Female		

2. Age of Participant

1. Below 20	2. 20-40	3. 41-50	4. Above 50
-------------	----------	----------	-------------

3. Marital Status

1. Single	2. Married	3. Divorced	4. Widower	5. Others (Specify)
-----------	------------	-------------	------------	------------------------

4. Are you the household head?

1.	Yes	
2.	No	

5. Indicate the number of people in the household per age category

1. 0-12	2. 1-5 years	3. 6-12 years	4. 13-19 years	5. 20-35	6. 36-59	7. 59 and above
---------	--------------	---------------	----------------	----------	----------	-----------------

6. Level of Education

1. No formal education	2. Primary Education	3. Secondary school	4. Tertiary education
------------------------	----------------------	---------------------	-----------------------

7. Employment status

1. Employment full time	2. Employment part time	3. Unemployed
-------------------------	-------------------------	---------------

8. Source of income

1. Wages	2. Salary	3. Pension	4. Grant	5. Others (Specify)
----------	-----------	------------	----------	------------------------

9. Average money in the household

1. Below 800	2. R801-R1500	3. R1501-R3500	4. Above R3500
--------------	---------------	----------------	----------------

B: Questions on *Mahewu*

1. Do you drink *Mahewu*? 1. Yes 2. No

2. I drink *Mahewu* because it is.... Tick

1.	It is my best beverage	
2.	It is wholesome & filling	
3.	It is very nutritious	
4.	It tastes very good	
5.	Not Applicable	

3. How frequently do you drink *Mahewu*?

1.	More than three times a day	
2.	Once a week	
3.	Once a month	
4.	Occasionally	

4. Tick the beverages you drink and the frequency

a. Coffee

1. Daily	2. Once a week	3. Not at all	4. Occasionally

b. Concentrated drink

1. Daily	2. Once a week	3. Not at all	4. Occasionally

c. Fizzy drink

1. Daily	2. Once a week	3. Not at all	4. Occasionally

d. *Mahewu*

1. Daily	2. Once a week	3. Not at all	4. Occasionally

5. Who drinks *Mahewu* within the household?

1	Only children under 5	
2	All the household members regardless of age	
3	Elderly	
4	Adult only	
5	Children above 5 years to 18 years only	

a. Which seasons of the year do you most consume *Mahewu* the most?

1. Autumn	2 Winter	3 Spring	4 Summer	5 Any season
-----------	----------	----------	----------	--------------

6. How often do you consume *Mahewu* during this season?

1.	Daily	
2.	Once a week	
3.	Once in a month	

4.	As often as possible	
----	----------------------	--

7. a. What do you add to your *Mahewu* before taking it?

1.	Fruits	
2.	Sugar	
3.	<i>Moringa</i> powder	
4.	Nothing	
5.	Others	

- b. Is there anything special added in *Mahewu* for children under 5 years of age?

1. Yes 2. No

Questions on Perception on Moringa

8. Are you familiar with *Moringa*? 1. Yes 2. No

9. Is *Moringa* a herb? 1. Yes 2. No

10. Can *Moringa* be added to food? 1. Yes 2. No

11. Have you ever used *Moringa*? 1. Yes 2. No

12. Have you ever used *Moringa* as food? 1. Yes 2. No

- a. In what form do you use *Moringa*?

1.	Fresh leaves	
2.	Just the root/stem	
3.	Commercially processed powder form	
4.	Not applicable	

- b. How often do you take *Moringa*?

1.	Every day	
2.	Once a week	
3.	Only when am sick	
4.	Never	

- c. Why have you not used *Moringa*? Because

1.	Not edible	
2.	Not indigenous to Ntambanana	
3.	Lack the knowledge on how to use it	

- d. If you were encouraged to take *Moringa* as food for health benefits would you?

Tick only one that applies to you

1.	I would happily use it	
2.	I would try it at least once	
3.	I am not sure	
4.	I would not use it	

- e. *Moringa* as food can be consumed by:

1.	Men of all ages	
2.	Woman of all ages	
3.	Children	
4.	None	

5.	All	
6.	Not Sure	

f. *Moringa* as medicine can be consumed by:

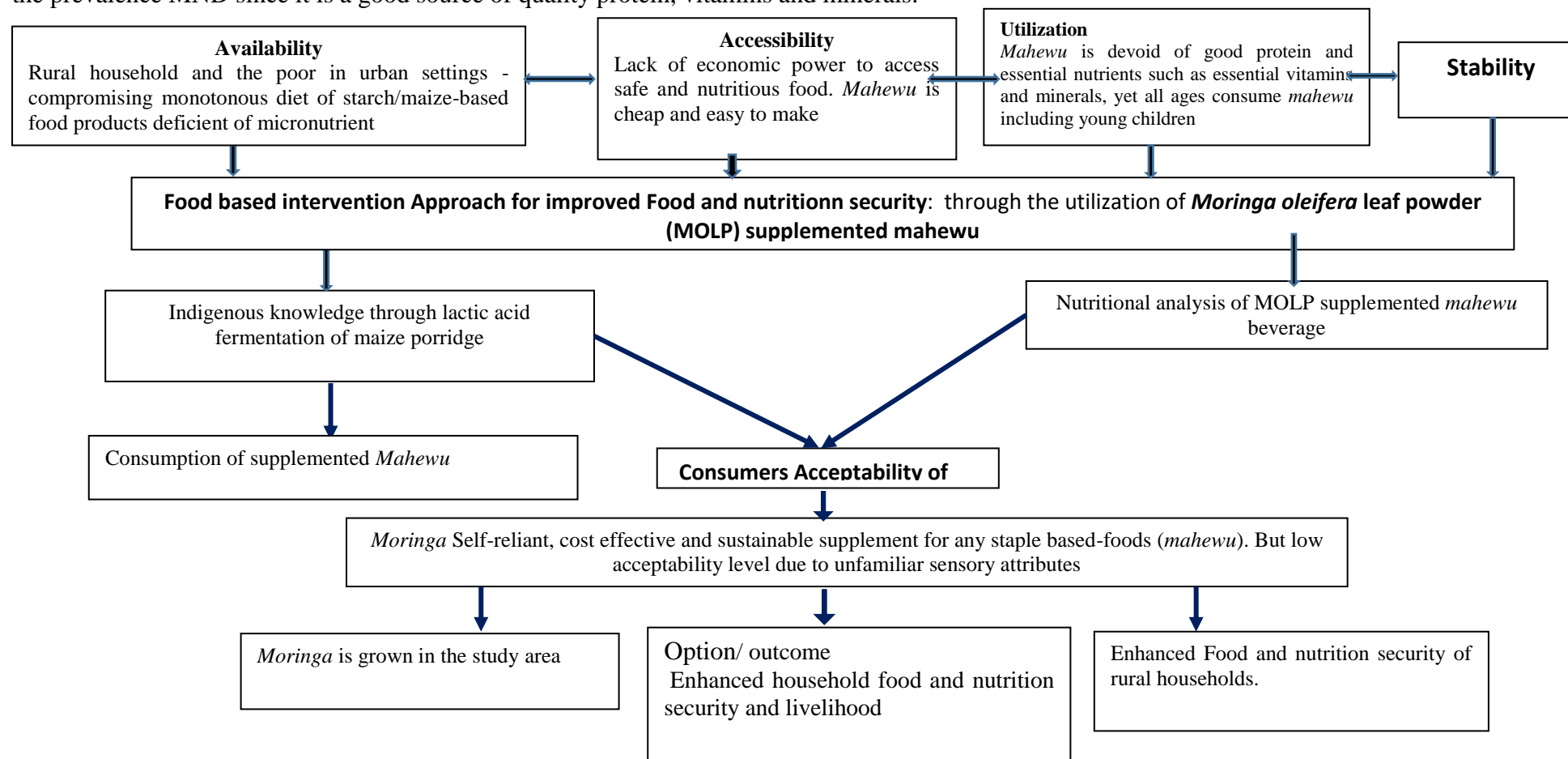
1.	Men of all ages	
2.	Women of all ages	
3.	Children	
4.	None	
5.	All	
6.	Not Sure	

g. *Moringa* as food supplement can be consumed by

1.	Men of all ages	
2.	Women of all ages	
3.	Children	
4.	None	
5.	All	
6.	Not Sure	

Appendix: N - The Conceptual framework of the study (adapted from Zungu (2016))

FOOD AND NUTRITION INSECURITY AND UNPRODUCTIVE LIFE – Micronutrient deficiency (MND) including poor protein cereal foods identified resulting to a burden of health problem globally and is on the rise in Sub-Saharan Africa and in South Africa. MOLP is potent of mitigating the prevalence MND since it is a good source of quality protein, vitamins and minerals.

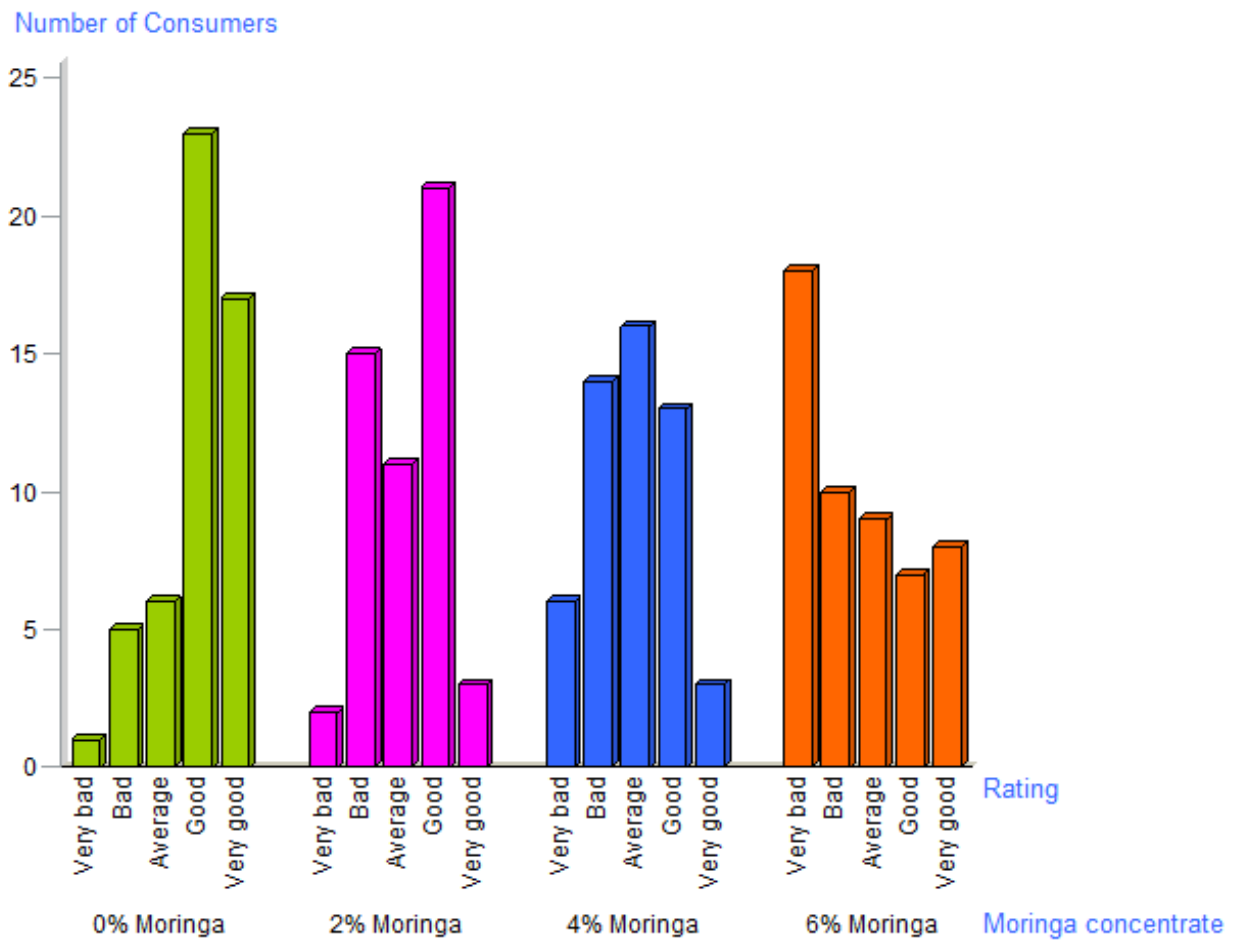


Appendix O: Table showing Overview of consumer acceptability of MOLP-supplemented mahewu

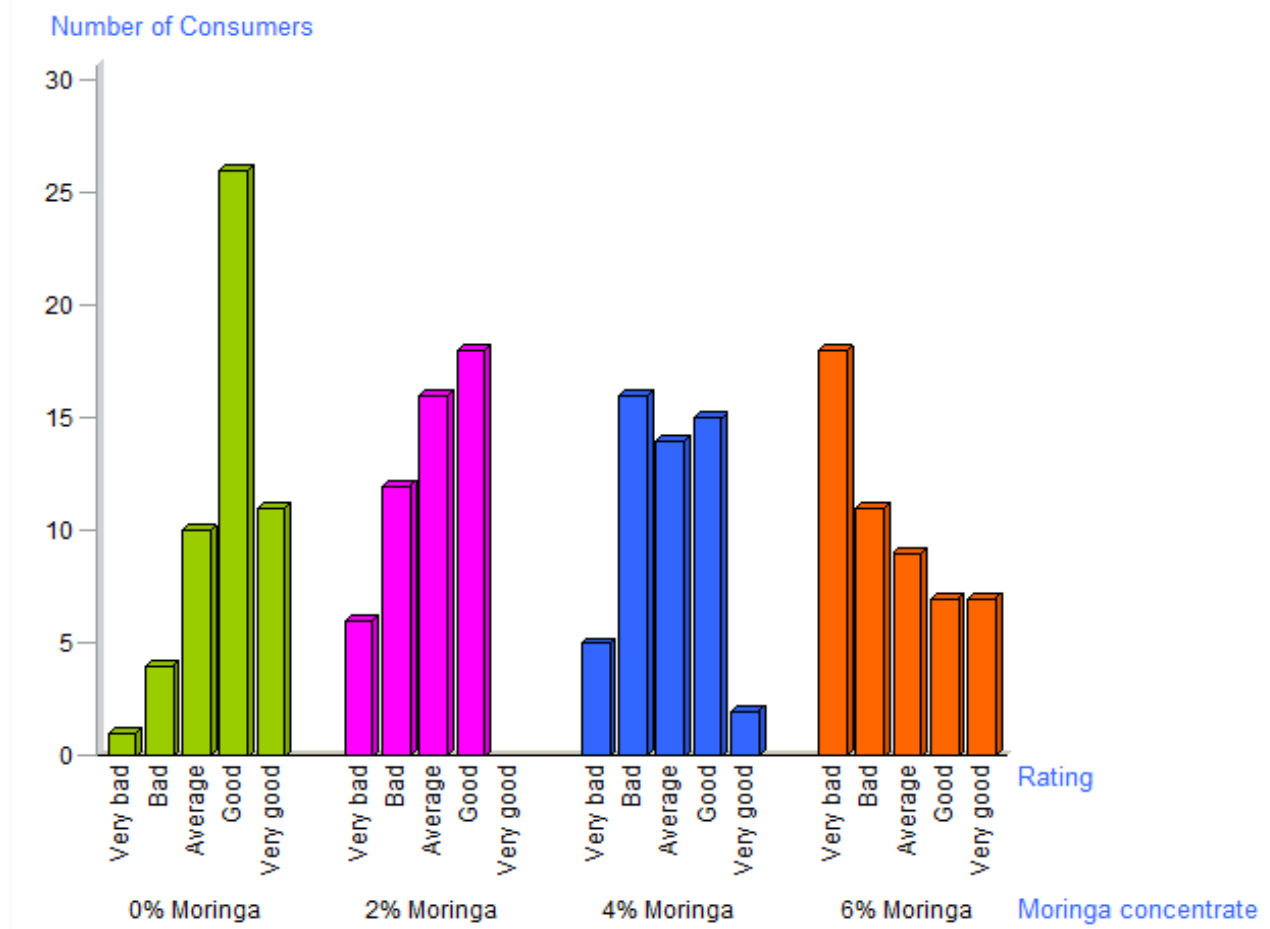
Sensory	Rating	0% <i>Moringa</i>	2% <i>Moringa</i>	4% <i>Moringa</i>	6% <i>Moringa</i>
	Very bad	1(1.9%)	2(3.8%)	6(11.5%)	18(34.6%)
	Bad	5(9.6%)	15(28.8%)	14(26.9%)	10(19.2%)
	Average	6(11.5%)	11(21.2%)	16(30.8%)	9(17.3%)
	Good	23(44.2%)	21(40.4%)	13(25%)	7(13.5%)
	Very good	17(32.8%)	3(5.8%)	3(5.8%)	8(15.4%)
Total		52(100%)	52(100%)	52(100%)	52(100%)
	Very bad	1(1.9%)	6(11.5%)	5(9.6%)	18(34.6%)
	Bad	4(7.7%)	12(23.1%)	16(30.8%)	11(21.2%)
	Average	10(19.2%)	16(30.8%)	14(26.9)	9(17.3%)
	Good	26(50.0%)	18(34.6%)	15(28.8%)	7(13.5%)
	Very good	11(21.2%)	0(0%)	2(3.8%)	7(13.5%)
Total		52(100%)	52(100%)	52(100%)	52(100%)
	Very bad	0 (0%)	4(7.7%)	3(5.8%)	8(15.4%)
	Bad	4(7.7%)	10(19.2%)	17(32.7%)	20(38.5%)
	Average	5(9.6%)	11(21.2%)	8(15.4%)	6(11.5%)
	Good	31(59.6%)	20(38.5%)	20(38.5%)	13(25.0%)
	Very good	12(23.1%)	7(13.5%)	4(7.7%)	5(9.6%)
		52(100%)	52(100%)	52(100%)	52(100%)
	Very bad	0(0%)	4(7.7%)	7(13.5%)	8(15.4%)
	Bad	2(3.8%)	10(19.2%)	13(25.0%)	18(34.6%)
	Average	5(9.6%)	9(17.3%)	8(15.4%)	11(21.2%)
	Good	29(55.8%)	24(46.2%)	18(34.6%)	9(17.3%)
	Very good	16(30.8%)	5(9.6%)	6(11.5%)	6(11.5%)
Total		52(100%)	52(100%)	52(100%)	52(100%)
	Very bad	0(0%)	4(7.7%)	5(9.8%)	13(25.0%)
	Bad	1(1.9%)	7(13.5%)	12(23.5%)	9(17.3%)
	Average	5(9.6%)	12(23.1%)	8(15.7%)	11(21.2%)
	Good	27(51.9%)	19(36.5%)	19(35.3%)	10(19.2%)
	Very good	19(36.5%)	10(19.2%)	8(15.7%)	9(17.3)
Total		52(100%)	52(100%)	52(100%)	52(100%)

Appendix P: - The graphical representation of an Overview of MOLP-supplemented mahewu sensory evaluation (0%, 2%, 4% and 6%) of MOLP-supplemented mahewu.

Color

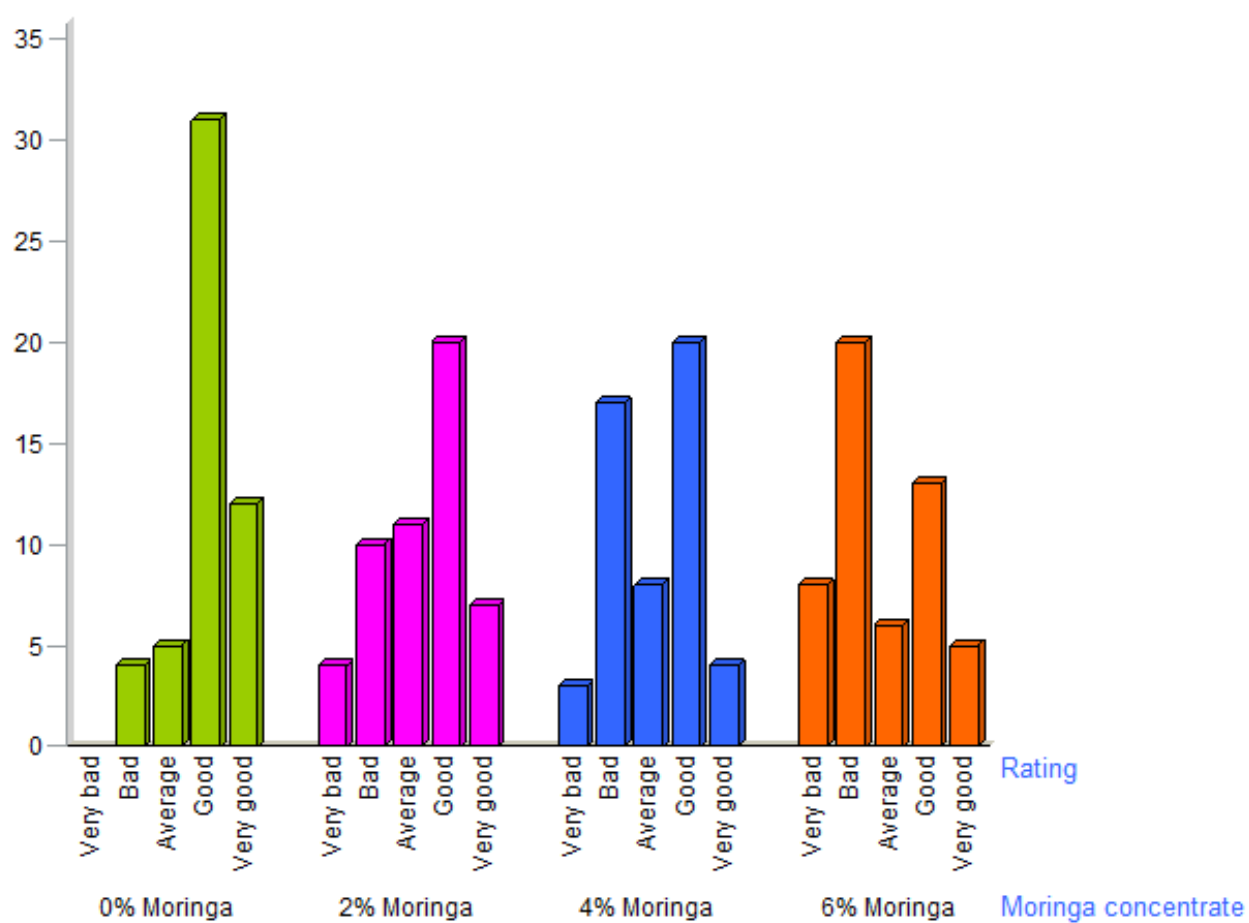


Aroma

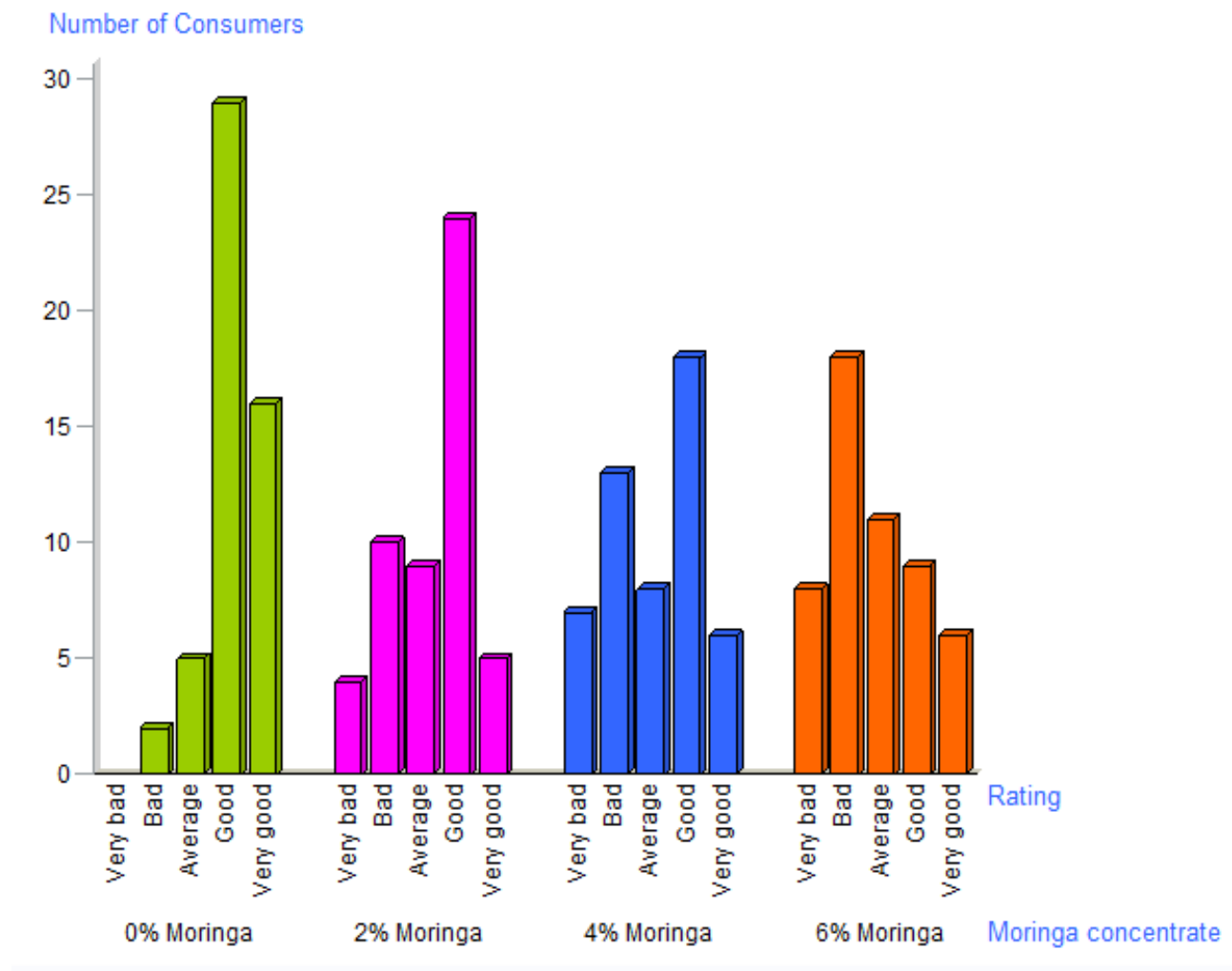


Mouthfeel

Number of Consumers



Taste



Overall acceptability

Number of Consumers

